# JOURNAL

OF THE

# AMERICAN SOCIETY OF NAVAL ENGINEERS.

VOL. XV. MAY, 1903. No. 2.



The Society as a body is not responsible for statements made by individual members.



COUNCIL OF THE SOCIETY
(Under whose supervision this number is published).

Captain G. W. BAIRD, U. S. N. Lieutenant Commander W. M. PARKS, U. S. N.
Lieutenant Commander J. R. EDWARDS, U. S. N. Lieutenant Commander F. J. SCHELL, U. S. N.
Lieutenant C. W. DYSON, U. S. N.


## SCREW PROPELLERS OF U. S. NAVAL VESSELS.


BY LIEUTENANT CHARLES W. DYSON, U. S. N., MEMBER.

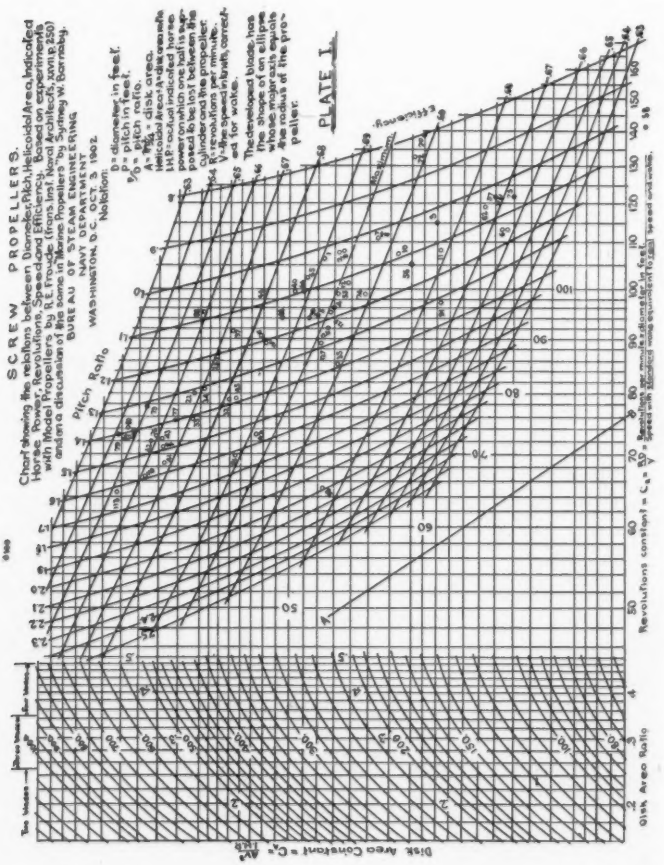

In making the following criticisms on the propellers of our vessels I have taken as the basis of my findings the efficiencies of performance of the different screws as shown by applying Froude's formulæ, using as data the actual data of the trials of the vessels.

In making use of these formulæ I have not used Table II, page 108, fourth edition of "Screw Propellers," by S. W. Barnaby, as a table, but have made use of it in the form of a logarithmic chart, shown on Plate I.

On this chart, on the left, are laid down the values of $C_A = \frac{AV^3}{\text{I.H.P.}}$ for different ratios of developed area to disc area, and on the right are the values of $C_R = \frac{RD}{V}$.

Cutting the lines of $C_R$ are the curves of pitch ratios and those of efficiency, the curve of maximum efficiency being shown as a dash line.

On this chart, as originally constructed, there are also curves of real slips, but, as these slip values are calculated for a standard wake of 10 per cent., I have not included the curves derived from them on the modified chart, as the actual wake coefficients may vary widely from this value.



### QUANTITIES EMPLOYED IN FROUDE'S FORMULÆ.

It is presumed that all my readers are thoroughly acquainted with the formulæ quoted above, but for the sake of clearness I shall give the values of the terms composing them.

In the formula $C_R = \frac{AV^3}{\text{I.H.P.}}$, $A$ is the disc area of the propeller, I.H.P. is the calculated horsepower required for the designed speed. $V$ is the speed of the water in which the propeller works and is equal to $MS$, $S$ being the speed of the vessel in knots per hour and $M$ the wake coefficient.

In the formula $C_R = \frac{R \times D}{V}$, $R$ is the desired number of revolutions of the propeller per minute, $D$ its diameter and $V$ the same as given in the preceding paragraph.

### METHOD OF USING THE FORMULÆ AND CHART.

Being given the indicated horsepower and revolutions of the engines, the maximum diameter of propeller that can be used, and the speed expected to be made by the vessel, and, having decided by experience upon the proper wake coefficient to use, we insert the first three quantities and the corrected speed in the formulæ for $C_A$ and $C_R$, using different values for the diameter of the propeller until possibly the maximum allowable diameter is reached.

These values of $C_A$ are measured up along the different disc ratio lines and projected over until the lines of projection intersect the ordinate at the corresponding value of $C_R$. Where one of these ordinates and its corresponding line of projection intersect upon the line of maximum efficiency, or preferably slightly above the line, we have plotted the desired pitch ratio of the propeller, the value of $D$, used for the corresponding value $C_R$, being its diameter, and the disc-area ratio line upon which the $C_A$ was measured being the ratio of the helicoidal area of the propeller to its disc area. Above the disc-area ratio ordinates are shown the limits of this ratio for two, three and four-bladed propellers as defined by good practice. These limits are, however, often departed from, through necessity, as in the cases presented by torpedo boats and destroyers.

In these latter cases, also, efficiency is deliberately sacrificed in order to prevent the occurrence of cavitation at high speeds and high powers, and the ratios given to the blades of propellers for these types of vessels are made very large in order to obtain the necessary amount of projected area.

I have plotted on the chart the positions of the screw propellers of our different vessels in order to serve as a guide in future designs.

In plotting these points I have noted one great peculiarity. Where cavitation has occurred, in cases where there can be no doubt as to its existence, the cavitating propeller has plotted at a point of equal or greater efficiency than those propellers that have been doing their work properly; they have been efficient in working against an undue resistance due to their own faulty design, this undue resistance having masqueraded as a legitimate resistance, due to the forms of the hulls of the vessels driven, until Mr. J. I. Thornycroft's experiments upon the propellers of the *Daring* placed the blame where it properly belongs.

A much better idea of the way the propeller is acting can be obtained by plotting its position on the chart, and from the corresponding speed $S$ and corresponding $C_R$ obtaining the value of $M$ of the wake coefficient. If this is abnormally high for that particular type of vessel, and the I.H.P. is unduly high, it shows that the vessel has reached her practical limit of speed with the propeller fitted, and the propeller is too small. If the speed aimed at has not been obtained and the engines have worked nearly or quite up to their full power while there is no extreme increase of slip nor of power, the propellers are too large. For a guide in such cases, data of performances of similar vessels are of great value.

This comparison of data is, however, not absolutely certain, and the most preferable method of checking the performance is to run a series of progressive trials up to the highest speed obtainable, and from the results obtained, lay down a curve of wake coefficients. If, towards the maximum speed obtained, the value of the wake coefficient increases abnormally, and the curve is still rising rapidly at the highest speed made, while the power

required for this speed is very high, the propellers are too small. If, however, the curve is tending downward at the greatest speed made, the propeller is either too large in area or the pitch is wrong for that particular speed.

### PLOTTING PERFORMANCE VALUES ON THE CHART, AND CONSEQUENT DETERMINATION OF WAKE COEFFICIENTS.

Of the following work criticism may be made that I am in error in assuming that the true working pitch of the propeller blades, whether set as cast or not, whether of expanding pitch or true pitch, is the same as the measured mean pitch, and have disregarded shape of blade, and that, therefore, the results obtained are not accurate. I cheerfully acknowledge the existence of error in this assumption and omission, but as any correction for form would be only guess work, and as there are no known means by which the true working pitch can be calculated, and as the departure from the measured mean pitch cannot be very great, I claim that the results obtained are a very close approximation to the actual results and are worthy of consideration.

In finding the position given on the chart to any propeller by its trial performance, I assumed for each of several vessels a a series of different values of $M$ from .9 to 1.2, and with the corresponding $V$'s worked out the corresponding values of $C_A$ and $C_R$ and plotted a series of positions for each propeller, using these series of values of the coefficients.

After plotting these different values for the propellers of each vessel, I discovered that the series of points for any one propeller fell in a perfectly straight line, and that these several lines for the several screws were all parallel, and were parallel to the line $A$—$B$. This line $A$—$B$, therefore, is the direction line for varying wake coefficient.

Where a line drawn through the positions obtained for a propeller by assuming any wake coefficient and drawn parallel to $A$—$B$ cuts the curve of pitch ratio will be the approximately correct position on the chart for this propeller. Taking from the chart the value of $C_R$ corresponding to this position, and knowing from our performance data the values of $D$, $R$ and $S$, we have from

$C_R = \frac{D \times R}{V}$ the value of $V = \frac{D \times R}{C_R}$, from which we derive $M = \frac{V}{S}$.

This method has been followed with all the vessels and the wake coefficients for the vessels found from their trial data. For those vessels which were subjected to progressive trials, and on which sufficient data for computation was taken, I have worked out the values of $M$ for each of the progressive speeds, and have plotted the curves of $M$ and corresponding I.H.P.'s to scale. These curves are shown on Plates II to XI inclusive. It must be noted that the chart, as constructed, carries a 10 per cent. wake correction, so that the wake coefficients, as found, are only correct for use with the chart.

From a comparison of the performances of similar vessels or of the same vessel with different propellers as shown by these curves, a very good idea of the effect on the wake and efficiency caused by variations of pitch, diameter and surface can be obtained and the causes of faults in existing propellers ascertained.

### DISCUSSION OF WAKE COEFFICIENT CURVES SHOWING EFFECT OF VARIATION OF ELEMENTS OF THE PROPELLER.

#### CASE I.—VARIATION OF SURFACE.

Plate II shows the curves of wake coefficients and of I.H.P. for the British armored cruisers *Drake* and *Good Hope*.

These two vessels are as identical in form as two vessels built from the same plans can be; they were tried on the same lines and draught, and over the same measured course.

Practically the only difference between the two vessels is in the propellers, of which those of the *Drake* possess about 50 per cent. more developed area than those of the *Good Hope*, are of the same diameter and have only three inches more pitch. The propellers may be regarded as identical in all respects but that of surface.

In the case of the smaller propellers the curve of wake coefficients is below unity from the lowest speed shown until a speed of twenty-two knots is attained, when their propulsive efficiency

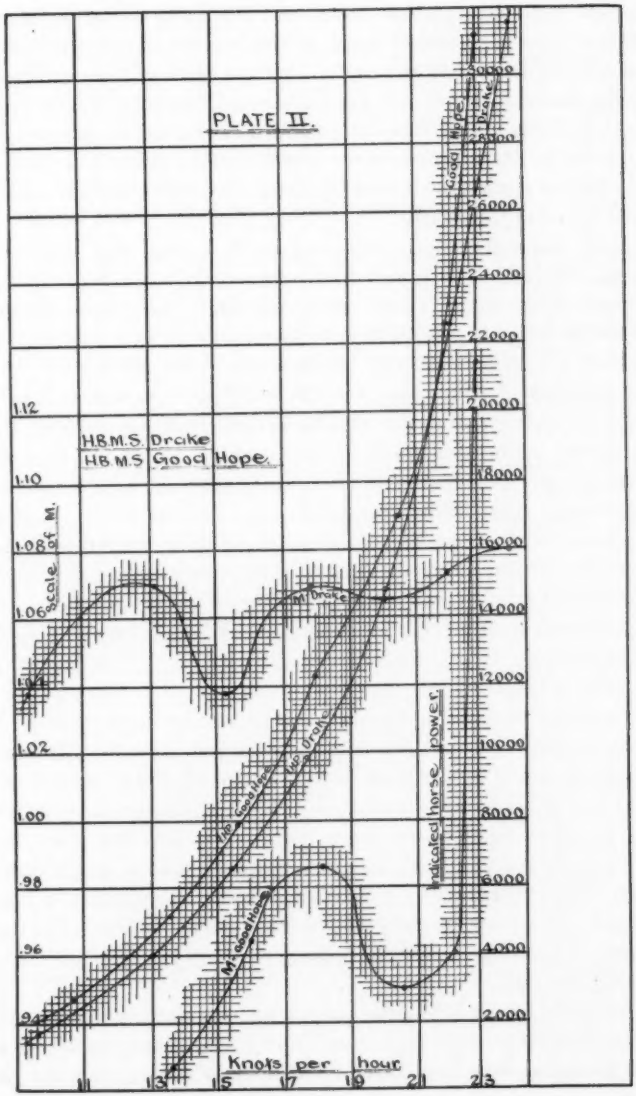


PLATE II.
H.B.M.S. Drake
H.B.M.S. Good Hope.
Scale of M.
Knots per hour
Indicated horse power
Good Hope
Drake
Mr Coudrey's Log
Mr Goodrich's
1.12
1.10
1.08
1.06
1.04
1.02
1.00
.98
.96
.94
30000
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
11
13
15
17
19
21
23

appears suddenly to break down, and the value of the wake coefficient rises very rapidly until at the highest speed attained it has reached the value of 1.134. The low value of the coefficient for the lower speeds is very probably nearly that due to the form of hull of the vessel, while the sudden rise at the higher speeds is caused by some defect in the screws. This defect is undoubtedly lack of surface, as is seen by comparing with the wake coefficient curve of the *Drake*.

Upon inspecting these latter curves, it is seen that the wake coefficient has been raised well above unity, and even at the highest speed made, 24.11 knots, has only risen very slightly above the value at ten knots and shows no sign of a tendency to sudden increase. This rise in the value of the wake coefficient can be credited to nothing but the increase in surface. It cannot be supposed that the smaller propellers have reduced the coefficient below that due to the form of the vessel, nor that the difference of three inches in pitch has made the change, for two other sister ships, whose propellers are identical in all respects but pitch with those of the *Good Hope*, show very nearly the same, but slightly lower, values of wake coefficient at the lower speeds, and much lower values at the higher ones. These vessels would seem to show that increase in pitch had some effect upon wake, tending to decrease its velocity slightly, while the effect of surface upon this velocity is very great.

That this increase of surface and consequent large increase in wake-coefficient values has had no bad effect upon the efficiency is seen at once by a glance at the curves of I.H.P. of the two vessels, the advantage in efficiency being throughout, except at one point, in favor of the larger screw. At this one point, the efficiencies are identical. Better results, however, might have been obtained with the *Drake*—better so far as efficiency is concerned—by giving slightly less surface to her screws than was given, as from her performance they plot too high on the chart, at 68.5 per cent.

*Ericsson.*—Plate III shows the curves of wake coefficients and I.H.P. of this torpedo boat, and, from the similarity in values of the curve of wake coefficients, and also in shape, showing the

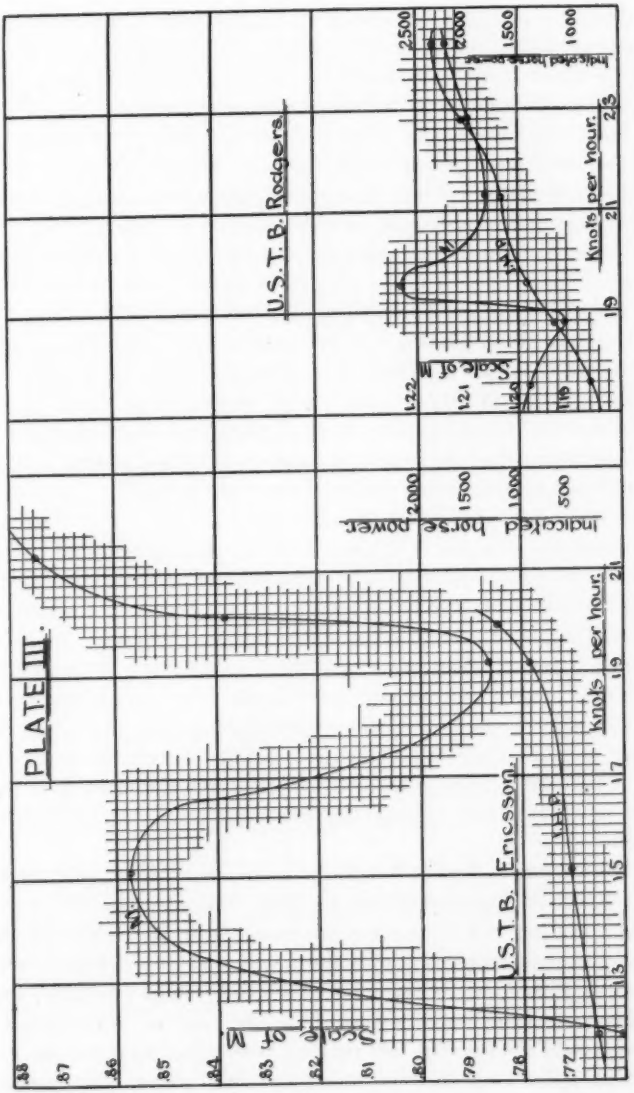


PLATE III.
U.S.T.B. Rodgers.
U.S.T.B. Ericsson.
Scale of M
Scale of M
indicated horse power.
indicated horse power.
knots per hour.
knots per hour.
88
87
86
85
84
83
82
81
80
79
78
77
2500
2000
1500
1000
500
1.22
1.21
1.20
1.19
1.18
1.17
1.16
1.15
1.14
1.13
19
21
23

sudden rise at about 19½ knots, we feel justified in assuming that the same defect existed in the propellers of this vessel as in those of the *Good Hope*. Good results might be expected from a very considerable increase in the area of these screws.

*Paul Jones*, *Perry* and *Preble*.—Plate IV shows the curves of wake coefficients and of I.H.P. of main engines of these three torpedo-boat destroyers. The hulls of these vessels are identical, and their trims and drafts on trial varied but little, so that the influence of form of hull was probably identically the same for all three.

The screws of all were of the same diameter. The pitches of the screws differed but a very few inches, that of the *Perry* being 10.83, of the *Paul Jones* 10.66 and of the *Preble* 10.4 feet. In surface, however, there was a wide dissimilarity between the propellers of the *Perry* and those of the other two vessels.

The *Perry* has propellers having only 16.83 square feet of developed surface, while those of the *Paul Jones* have 24 square feet, and of the *Preble* 20.33 square feet.

There are two sets of curves of wake coefficients and of I.H.P. for the *Perry*, those of 1901 being considered the most accurate, the high values throughout of the 1902 curve of coefficients casting a doubt on the accuracy of the observations. By comparing these curves of 1901 with those of the *Paul Jones* and the *Preble*, it is seen that so long as the wake coefficient of the *Perry* is less than those of the other two the propellers are more efficient, but upon passing above these curves the smaller screws of the *Perry* immediately fall in efficiency below the other two, and the power for that vessel increases rapidly as compared with theirs.

The curves of the *Preble* and the *Paul Jones*, on the other hand, have reached their first maximum value at about 26 knots. From that speed on, the wake ratio decreases until, in the case of the *Preble*, it has reached a minimum value at 28¼ knots. After passing this speed it begins to rise, and would probably have continued rising rapidly with little increase of speed of the vessel until the engines had reached their maximum power.

The wake coefficient curve of the *Paul Jones*, after passing

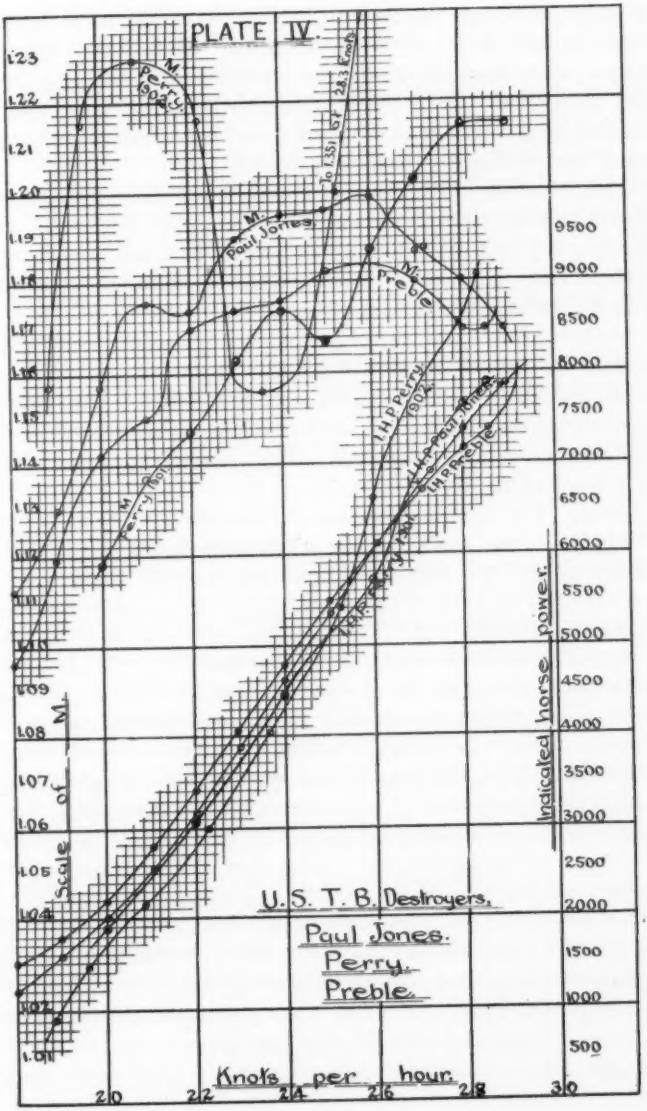


PLATE IV.
M. Perry 1902
No 1.151 Gt 28.3 Knots
M. Paul Jones
M. Preble
I.H.P Perry 1902
I.H.P Paul Jones
I.H.P Preble
M. Perry 1901
Scale of M.
Indicated horse power.
U.S.T.B. Destroyers.
Paul Jones.
Perry.
Preble.
Knots per hour.
1.23
1.22
1.21
1.20
1.19
1.18
1.17
1.16
1.15
1.14
1.13
1.12
1.11
1.10
1.09
1.08
1.07
1.06
1.05
1.04
1.03
1.02
1.01
9500
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
2.0
2.2
2.4
2.6
2.8
3.0

26 knots, continues falling until the highest speed made by the vessel was reached. Even at this speed there is no tendency towards an upward inflection, the additional area of her propellers over those of the *Preble* having evidently rendered them capable of producing a yet higher speed than that realized, although being less efficient for the speeds made.

The propellers of the *Perry*, at speeds lower than 26 knots, are decidedly more efficient than those of the other two vessels, but after passing that speed and a wake coefficient value of 1.2, they become very much more inefficient, this inefficiency increasing with the speed and the wake velocity.

In these cases again, the only practical difference of any great amount in the propellers is in developed surface, and, without doubt, the lower values of the wake velocity ratios at the highest speeds attained by the *Paul Jones* and the *Preble* are caused by the large increase in the surface of the propellers of these vessels over those of the *Perry*.

(Note.—The broken character of the wake coefficient curves of the *Paul Jones* and the *Preble* is probably caused by too much fairing of the I.H.P. and of the revolution curves.)

### CONCLUSIONS AS TO EFFECT OF SURFACE.

From the above examples it appears that the effects of large surface are to raise the wake coefficient values at both moderate to moderately high speeds, and to reduce them at very high speeds. Both of these modifications of the values of the wake coefficient may be, and the latter is, accompanied by gain in efficiency, the speed at which this gain occurs, however, depending upon the form, size and practical maximum speed of the vessel.

### NORMAND'S RULE FOR SURFACE.

For all vessels of high speed where cavitation is likely to occur, Mr. J. A. Normand gives the following rule from which to calculate the proper amount of developed area:

$$\triangle^2 r^2 = J\frac{F}{S^2},$$

where

$\triangle$ = the diameter of the propeller in meters.

$r = \frac{\text{total helicoidal area}}{\text{total disc area}}$.

$F$ = maximum power in horsepower of 75 kilogram meters applied to one propeller.

$S$ = corresponding speed of the vessel in knots per hour.

$J$ = a coefficient which experience shows should be all the greater as the sharpness of the hull relatively to the speed is less, and should never be less than .60. It may with advantage exceed .80.

"For over three years, this rule has received numerous confirmations."

Changing this rule to English units, and adopting a value of $J = .70$, the rule, when transposed for finding the value of $r$, the disc ratio, becomes

$$r = \sqrt[3]{\left(\frac{7.43 \times \text{I.H.P.}^4}{S^2 d^2}\right)},$$

where $d$ = the diameter in feet.

In his discussion of the subject of cavitation, Mr. Normand makes the following statement: "The amount of motion communicated to the water by the propeller measures the resistance of the vessel. If the speed, which forms one of the factors of that amount of motion, is great enough to produce cavitation, the increase of the other factor follows; the liquid mass, which is proportional to the propelling surface." In other words, if the speed of the water in the propeller race is sufficient to produce cavitation, it becomes necessary to increase the amount of propelling surface and, therefore, the amount of liquid mass acted upon at each instant, in order to prevent it.

This reasoning appears to be fully sustained by the character of the wake coefficient curves already given.

Barnaby, however, bases his rule for surface upon the amount of effective thrust per square inch of projected area as determined by the *Daring* experiments, limiting it to 11¼ pounds in vessels of that type and having about the same immersion of propellers. This amount may, however, be slightly increased where the im-

mersion of the propellers is greater, due to the increased head of water producing an increase of speed of feed in the propeller race. The pressure (effective thrust) allowed by Barnaby is $11\frac{1}{4}$ pounds per square inch of projected area with an increase of $\frac{3}{8}$ pound for every foot immersion over 11 inches.

### Case II.—Variation of Diameter.

*Katahdin.*—Plate V shows the curves of wake coefficients and of indicated horsepower for two different sets of propellers tested on this vessel.

Curves No. 1 are for propellers having a diameter of 10 feet $10\frac{1}{2}$ inches, pitch 14 feet 4 inches, and developed area of 38.56 square feet. Curves No. 2 are for propellers whose diameter is 12 feet, pitch 14 feet, and developed area 36.25 square feet. These latter screws were the ones finally adopted as best suited to the vessel.

By inspection of the dimensions of these two sets of propellers it is seen that the only material difference between them is in their diameters, yet there is a very large difference in the velocity of the wakes produced by the two types; that of No. 1 being excessively high, while that of No. 2 holds well down near unity until after a speed of 16 knots is reached, when the wake coefficient curve rises almost vertically.

The powers required by the two types are identical until a speed of 11 knots is reached, when the efficiency of No. 1 falls off rapidly, approaching again towards No. 2 as 16 knots is approached. From the direction of the I.H.P. curves at a speed of 16 knots, it can be seen that shortly after passing this speed the efficiency of the propellers would be again equal. From the character of the wake coefficient curve of No. 2, we should judge that the vessel has reached her practical limit of speed at a little above 16 knots, and if so, all propellers capable of producing this speed should, at this limit of speed, be equally efficient. If this limit of speed has not been reached, it appears from the character of the curves that No. 1 propeller would be the better screw for speeds exceeding 16 knots.

As the above propellers are very close to each other in all

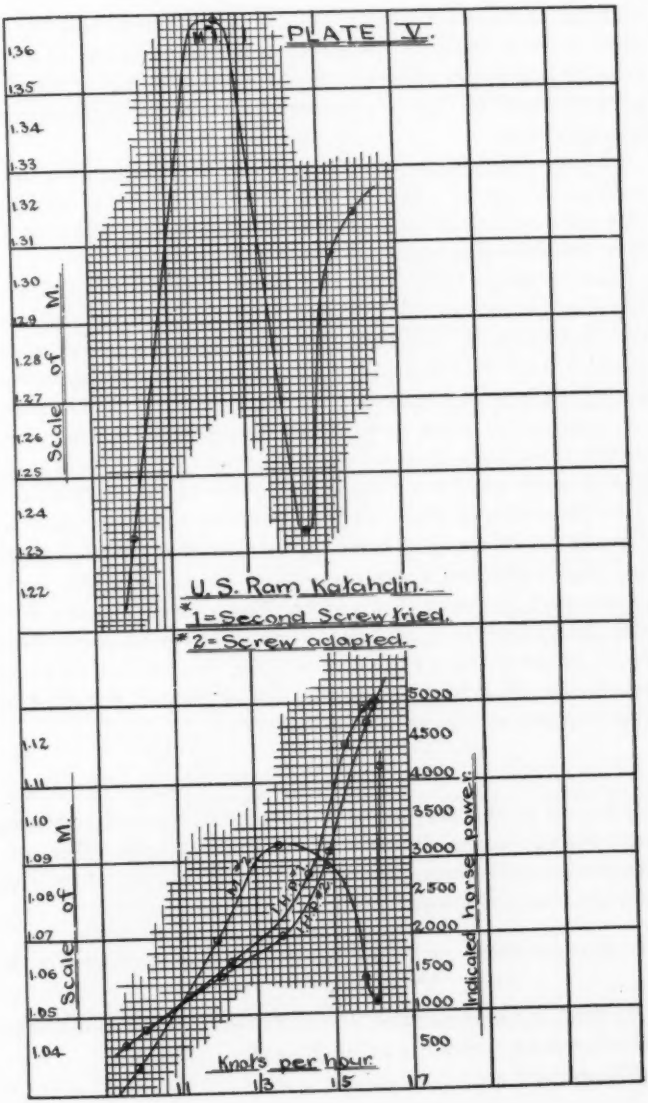


PLATE V.
U.S. Ram Katahdin.
*1=Second Screw tried.
*2=Screw adapted.
Scale of M.
Indicated horse power.
Knots per hour.
1.36
1.35
1.34
1.33
1.32
1.31
1.30
1.29
1.28
1.27
1.26
1.25
1.24
1.23
1.22
1.12
1.11
1.10
1.09
1.08
1.07
1.06
1.05
1.04
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
11
13
15
17

dimensions except diameter, the gain in efficiency and the low value of wake coefficient shown by No. 2 propeller can be credited only to its larger diameter, while the probably higher efficiency of No. 1 above 16 knots is undoubtedly due to its slightly greater projected area.

*Arkansas* and *Wyoming*.—Plate VI shows the curves of wake coefficients and of I.H.P. of these two coast-defense monitors. The hulls and machinery of these two vessels are identical, but they are fitted with screws differing quite widely.

The propellers of the *Arkansas* have a diameter of 9 feet, pitch of 7 feet 3 inches and a developed area of 25.6 square feet, while the corresponding dimensions of the *Wyoming's* propellers are 8 feet, 8 feet 6 inches and 25.8 square feet. The projected surfaces are nearly identical.

Variations in pitch, as we have already seen in the cases of British *Good Hope* class of ships, tend to vary the wake coefficient slightly and have a considerable effect upon efficiency.

By inspection of Plate VI it is seen that the wake-coefficient curve of the *Wyoming* is much higher than that of the *Arkansas*, this high coefficient curve being in all probability due, for the greater part, to the small diameter. The greater efficiency of the *Arkansas* propeller is probably due to its large diameter alone, for, as will be shown by the curves of the *Newport* and *Vicksburg*, decrease in pitch tends to increase the velocity of the wake and either reduce or increase the efficiency.

### CONCLUSIONS FROM CASE II.

Increase in the diameter of the propeller, the surface remaining constant, causes decrease in wake velocity, the effect upon the efficiency, however, depending upon the locality of the chart in which the performance of the screw plots it.

### EFFECTS ON DESIGN OF SCREW CAUSED BY VARYING ELEMENTS, AS SHOWN BY THE CHART.

In studying this question I have taken three general cases as covering most nearly the entire ground.

These cases are:

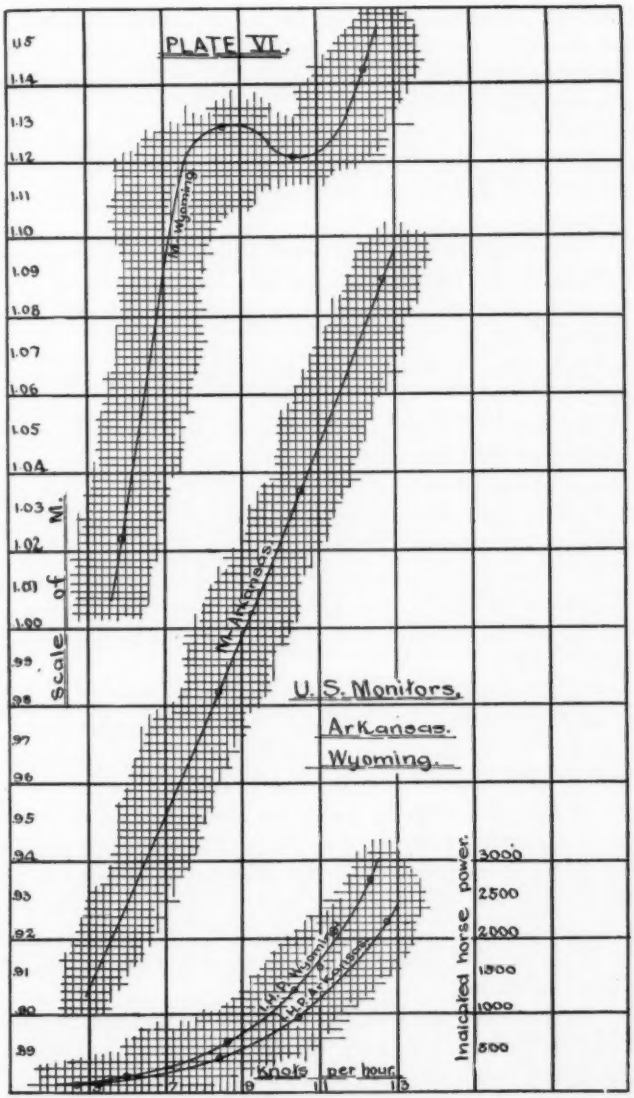


PLATE VI.
U.S. Monitors.
Arkansas.
Wyoming.
Scale of Ms.
Indicated horse power.
3000
2500
2000
1500
1000
500
Knots per hour.
I.H.P. Wyoming
I.H.P. Arkansas
M. Wyoming
M. Arkansas

20

(1.) With constant I.H.P., revolutions of propeller, speed of vessel, diameter and developed area of propeller, how will the efficiency and the pitch ratio of the propeller be affected by variation in the wake coefficient?

(2.) With constant wake coefficient, revolutions, power and developed area and speed of vessel, but with varying diameter of propeller, what will be the effect upon the efficiency and the pitch ratio?

(3.) With constant I.H.P. and speed of vessel, wake coefficient and efficiency, but varying diameter and developed area of propeller what effect do such variations have upon the pitch ratio and the revolutions?

To these three questions the chart gives us the following replies:

(1.) (*a.*) Should our data plot the propeller well below the maximum curve of efficiency, as we increase the value of the wake coefficient the pitch ratio increases very rapidly at first, but the rate of increase decreases as we draw near the line of maximum efficiency. The efficiency increases with the pitch.

(1.) (*b.*) Should the curve derived from the data cross the line of maximum efficiency, the pitch ratio continues increasing gradually, but the efficiency increases to the maximum and then decreases slowly.

(1.) (*c.*) After passing the line of maximum efficiency the pitch ratio continues increasing slowly with the rate of increase, becoming greater the farther away we get from the line of maximum efficiency, while the efficiency decreases rapidly.

(2.) In this case, with the points so plotting as to cross the curve of maximum efficiency, the pitch ratio decreases rapidly as the diameter increases, while the efficiency increases rapidly to the 69 per cent. efficiency line, then increases very slowly to and decreases very slowly from the maximum line until the upper curve of 69 per cent. efficiency is reached, when the rate of decrease is accelerated.

(3.) As the developed area and the diameter increase, in order to maintain the same efficiency, the pitch ratio and the pitch increase rapidly, while the revolutions must decrease.

CRITICISM OF PROPELLERS.—DESCRIPTION OF TABLES.

In order to place the results of these criticisms in a convenient form for reference I have prepared the appended tables.

In these tables the data on the first line for each vessel are those of the design, except the hull coefficients. In those cases where the trial data of the hull could be obtained the coefficients are usually those of the trial.

The data on the second line are those of the trial, including the data of the propellers used and the wake coefficient from the trial results.

On the third line are given the data of the propellers which I consider as preferable for high speeds to the propellers actually fitted. These preferable propellers have been worked out with the corrected wake coefficients given on this line. The slips given on this line are higher than the slips would actually be, and the speeds are lower.

In preparing these tables of data one is most thoroughly impressed with the advisability of collecting all the information possible concerning the performances on trial of both ships and their machinery. With the record of performance of either missing, that of the other has comparatively little value for future use, so far as combined efficiencies of hull and machinery are concerned. If, for instance, the engines of all our torpedo boats and destroyers had been indicated during their trials, complete data could have been given, and our knowledge of the requirements for these high-speed vessels greatly increased.

CRITICISMS.—BATTLESHIPS.

(1.) *Indiana*, *Massachusetts* and *Oregon*.—By referring to the table of propellers, it is seen that the propellers of the *Indiana* and the *Massachusetts* are identical in their proportions, while those of the *Oregon* differ from the others in pitch, diameter and surface, the first two elements of the *Oregon's* propellers being smaller, while the surface is much larger.

With the *Oregon's* propellers, over one-half knot more speed was realized with fewer revolutions than in the case of the *Massachusetts*, which made the second best performance. The results

of the *Oregon's* trials plot at 68.5 efficiency with a wake coefficient of unity, while the results of the *Massachusetts* plot her propellers at nearly maximum efficiency, those of the *Indiana*, however, plotting of slightly less efficiency and above the maximum line.

The wake coefficient of the *Massachusetts* corresponding to her performance is 1.179, and that of the *Indiana* 1.232.

The low position on the chart of the *Oregon's* propellers indicates lack in diameter and surface and excess of pitch, while the high wake coefficient values of the *Massachusetts* and the *Indiana*, at their maximum speeds, together with the character of the wake coefficient curve of the *Massachusetts*, as shown on Plate VII, are indications of the same faults in diameter and surface at higher speeds than that realized. For speeds below their trial speeds the propellers are too large.

The *Illinois*, whose record on trial is one of the best, made a speed of 17.45 knots per hour with a wake coefficient of only 1.04. This value I have taken as the proper one to use for the type of vessel under consideration.

By comparing the general dimensions and hull coefficients of the *Oregon* class of vessels with those of the *Illinois*, it is seen that the two classes are sufficiently close together to permit of using Froude's law of comparison with expectation of actual results closely approximating the calculated ones.

Applying this law and obtaining the corresponding speed for 10,890 I.H.P., assuming that the powers vary as the 3.5 power of the speeds, a speed of 17.2 knots appears possible. While this speed may be too high, I have used it in the calculations for the proposed screw; also using the I.H.P. of the *Oregon* and 132 revolutions of the propellers.

As the performances and wake coefficients of these vessels indicate too small diameters and surfaces for higher speeds than made, and as the propellers of the *Massachusetts* and the *Indiana* are of larger diameter than those of the *Oregon*, it is assumed that no greater diameter than that of the first-mentioned propellers can be used, and the other dimensions are obtained by using the values of $C_A$ and $C_R$ corresponding to this diameter.

Comparing the resultant screw with the actual screws of the

three vessels, those of the *Oregon* are seen to approach more nearly to it, while those of the *Massachusetts* and the *Indiana* differ considerably both in pitch and in developed area. The indicated thrusts per square foot of projected area of the propellers of all three vessels are high.

The blades of the resultant screw are very broad, and a better shaped blade would be obtained by using a propeller of greater diameter, if possible.

*Iowa.*—The trial results of this vessel plot her propellers very close to, but below, the maximum efficiency line. This position, together with the indicated thrusts and the wake coefficient 1.102, indicate that the propellers fitted are of too small area to realize any better results than those of the trial.

Using the speed, I.H.P. and revolutions developed on trial and a wake coefficient of 1.04, that of the *Illinois*, we derive our resultant propeller. This propeller, as is the case with all in which I have used the results of the trials as data, would be slightly too large for maximum efficiency under trial conditions, but would approach more nearly to the maximum when the vessel would be loaded down to her cruising draught.

The propellers fitted had too high a pitch and too small surface, giving a high percentage of slip and a high value to the indicated thrust per square foot of projected area.

*Maine* (old.)—The trial results of this vessel are doubtful on the point of speed, but the speed as given is probably very close to the actual speed.

The results of the trial plot these propellers as of 69 per cent. efficiency and on the upper side of the maximum line, with a wake coefficient of 1.09. The position of the plotted point indicates that these propellers possessed ample surface and were capable of taking care of still higher power than that developed without loss of efficiency. The wake coefficient appears to be a little high, but this value may be on one of the downward inflections of the wake coefficient curve, and, if so, at a higer speed would have a lower value.

It is doubtful whether these propellers could have been improved.

*Texas.*—This vessel is very short in proportion to her beam, and the probabilities are that the wake velocity ratio due to the form of hull alone is much less than unity. If this is the case, the curve of wake coefficients can be raised considerably by a proper proportioning of the surface of the propellers. The propellers fitted to the *Texas* have evidently had this effect, but the amount of surface given them has been excessive, as from the trial results the efficiency plots at 68.3 per cent. and above the maximum line, while the wake coefficient for the trial speed has a value of 1.13. By using a propeller of less surface the wake coefficient may still be kept up and an efficiency of 69 per cent. realized. I have selected for use a wake coefficient of 1.07, although it may be a little too high.

The resultant propeller has considerably less surface and less pitch than those fitted, while the plotted efficiency has risen to 69 per cent., and the thrust per square foot of developed and projected areas has increased until that per square foot of projected area is about equal to that of other vessels of the same general type and speed.

*Alabama, Illinois, Kentucky, Kearsarge* and *Wisconsin.*—Plate VII shows the wake coefficient and I.H.P. curves for the *Alabama*, the *Kearsarge* and the *Massachusetts*, as derived from the progressive-speed trials of these three vessels. The wake coefficients of and powers required for the *Alabama* at the lower speeds are considerably higher than those of the *Kearsarge*, and are lower for the higher speeds.

The propellers fitted to the *Illinois* are identical with those fitted to the *Kearsarge* and the *Kentucky*, and, as with these propellers much higher power and speed were developed by the *Illinois* than were developed by the *Alabama*, it would be preferable to work from these results rather than from those of the *Alabama*. At 17 knots the wake coefficient of the *Alabama* has a value of 1.002, while at 17.45 knots the wake coefficient of the *Illinois* has reached a value of 1.04.

Using this latter value of coefficient, and proportioning the propellers so that they will plot at 69 per cent. efficiency above the maximum line, we obtain a resultant propeller identical with

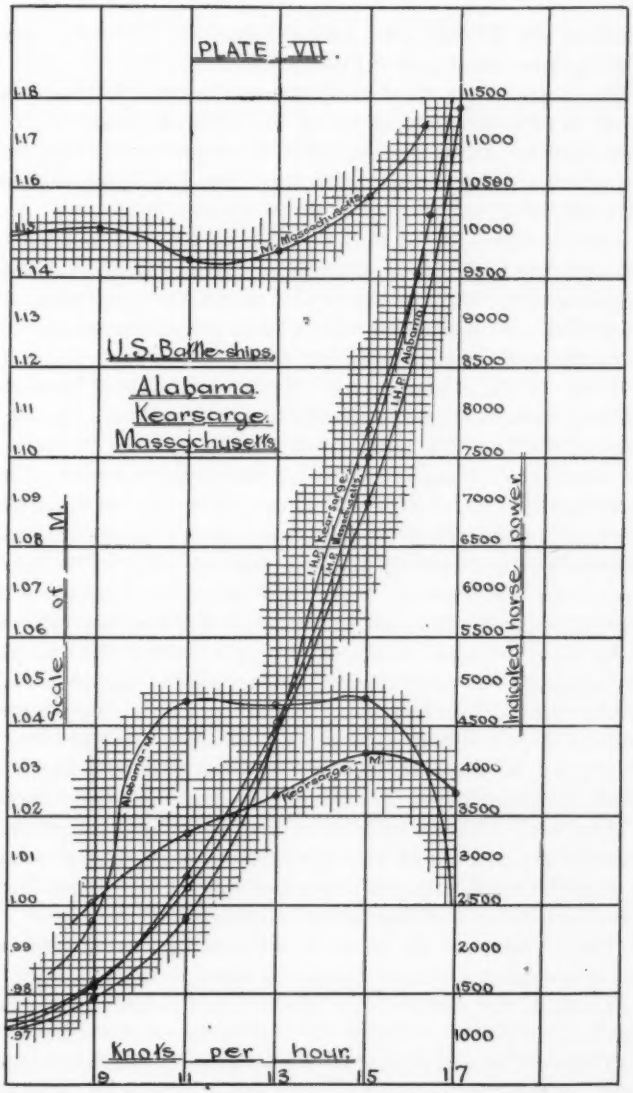


PLATE VII.
U.S. Battle-ships,
Alabama.
Kearsarge.
Massachusetts.
Scale of M.
Indicated horse power.
Knots per hour.
9
11
13
15
17
1.18
1.17
1.16
1.15
1.14
1.13
1.12
1.11
1.10
1.09
1.08
1.07
1.06
1.05
1.04
1.03
1.02
1.01
1.00
.99
.98
.97
11500
11000
10500
10000
9500
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
M. Massachusetts
I.H.P. Alabama
I.H.P. Kearsarge
I.H.P. Massachusetts
M. Alabama
M. Kearsarge

those of the *Illinois*, the *Kearsarge* and the *Kentucky*, but of slightly more developed surface.

The propellers of the four vessels first named plot, from their trials, as of 69 per cent. efficiency, but below the maximum line, thus showing lack of surface, while the propellers of the *Wisconsin*, which are very much smaller than the others, plot as of only 67.6 efficiency, and also below the maximum line.

The propellers of the *Wisconsin* will probably be much more efficient than those of the other vessels at low speeds, but at the higher speeds, which are the important ones for a war vessel, her propellers are a disappointment. These propellers are too small in diameter, and have insufficient surface.

Those of the *Alabama* lack diameter and a small amount of surface, while those of the remaining three vessels are lacking in surface, but only to a small extent.

*Maine* (new), *Missouri* and *Ohio*.—The propellers of the *Maine* were cast for a much higher mean pitch than that at which they were set on the trial of the vessel, so there is probably considerable difference between the true working pitch of the blades and the measured pitch. As there is no way by which the actual working pitch can be found, I have used the mean measured pitch.

By using the mean measured pitch, the result of the trial plots the propellers at 69 per cent. efficiency for the speed obtained. If the true pitch is less than the measured pitch, the efficiency will be a little lower. The wake coefficient corresponding to this speed is, however, too high for best results, being 1.125, while the thrust per square foot of projected area is also high.

Assuming a wake coefficient of 1.04, and giving the propeller the greatest area ratio commonly used for large ones, we obtain a propeller considerably less in pitch than those of the *Maine*, the *Missouri* and the *Ohio*, and of much greater area.

The propellers of the *Maine* lack in diameter and surface and are of too great a pitch to obtain the best results.

Those of the *Missouri* lack in surface and have too great a pitch.

Those of the *Ohio*, which are similar in all dimensions to those used on the *Wisconsin*, where they were inefficient as compared

with the propellers of her sister ships, lack diameter and surface and have too much pitch, but are not of as great a pitch as the propellers for the *Maine* and the *Missouri.*

If the propellers of the *Missouri* are properly designed to meet the requirements, it is hard to see how those of the *Ohio* can even approximate to them.

ARMORED CRUISERS.

*New York* and *Brooklyn.*—The propellers of these two vessels, while giving good results so far as speed realized, were both unfitted for the work. The wake coefficient of the *New York's* propellers, the smaller of the two sets, was very high, reaching a value of 1.284 at the speed made on trial.

The wake coefficient of the *Brooklyn's* propellers for the trial speed fell to 1.136, which was more nearly what it should have been for a vessel of that type.

There is no doubt that the efficiency of the *New York's* propellers would have been increased and the slip very much decreased by so designing the propellers as to cause a lower wake coefficient. An improvement in the performance of the *Brooklyn* very probably would also have occurred if a similar change had been made.

The wake coefficients for the British *Drake* and our *Olympia* were 1.08 and 1.074. The *New York* and *Brooklyn*, while not as fine lined as the *Drake*, are equal to the *Olympia*, and their wake coefficients should be no higher than for that vessel.

Take 1.08, the wake coefficient of the *Drake*, as that to be used for these two vessels. We see by comparison with the resultant propellers, which are designed to plot at the same efficiency height on the chart as those of the *Drake*, that the propellers of both vessels under discussion lacked seriously in surface and were of excessive pitch, while those of the *New York* were of too small diameter.

PROTECTED CRUISERS.

*Baltimore* and *Philadelphia.*—These two vessels are very close to each other in their general dimensions, and were designed for the same speed, revolutions and I.H.P. of main engines. The

*Baltimore* made considerably more than her designed speed, exceeded her designed revolutions and I.H.P., and her wake coefficient was quite low, 1,064, about its proper value.

The *Philadelphia*, on the other hand, made a fraction of a knot over her designed speed, exceeded her designed revolutions and fell short in her I.H.P., while the wake coefficient was entirely too high, being 1.15.

While the efficiency of the *Baltimore's* propellers under trial conditions was such as to indicate that the propellers were slightly too large, yet the efficiency of the propellers would increase as the resistance was increased, and the speed was decreased by loading the vessel down to her cruising draught. These propellers could hardly be improved.

Using the wake coefficients of the *Baltimore* in order to obtain the resultant propeller for the *Philadelphia*, and taking as data the designed I.H.P., 120 revolutions and an estimated speed of 20 knots, we obtain a screw identical with that of the *Baltimore*, but having slightly less pitch.

By comparing the *Philadelphia's* propeller with the resultant propeller, we see that in changing the pitch of the propellers from the cast mean pitch a mistake was made in increasing instead of decreasing the pitch for the trial.

The same propellers could be used for these two vessels, the blades being easily adjustable to suit either.

*Newark* and *San Francisco*.—These two vessels are of similar design of hull, and were designed for 19 knots speed, one contractor estimating 8,500 I.H.P. as necessary for that speed, while the other estimated 9,000 I.H.P.

The *Newark* on trial developed 8,582 I.H.P. with 127 revolutions, and made a speed of 19 knots. The wake coefficient, however, was abnormally high, reaching 1.193 at this speed.

The *San Francisco*, on the other hand, developed 9,581 I.H.P. with 124.8 revolutions, while the speed was 19.51 knots. The wake coefficient at this speed was only 1.016.

While the propellers of the *San Francisco* were smaller in diameter than those of the *Newark*, the pitch was also less. The

developed surface of the propellers of the *San Francisco* was considerably greater than that of the *Newark*.

Although the propellers of the *San Francisco* were less in diameter and in pitch than those of the *Newark*, and on trial the vessel drew considerably more water than did the latter-named vessel, the effect of the larger area of the blades was to reduce the slip and the number of revolutions, and to allow the engines to exceed considerably their designed power.

Using a wake coefficient of 1.02, and using the diameter of the *Newark's* propeller in order to have a slimmer blade, we derive a propeller with the same projected area and efficiency as that of the *San Francisco*, but of slightly less pitch and less developed surface.

The present propellers of the *San Francisco* could hardly be bettered where a speed propeller is required for these vessels.

*Cincinnati* and *Raleigh*.—These two vessels are sister ships, with hulls, engines and propellers identical in design. The *Cincinnati* has never had a speed trial, but one has been undergone by the *Raleigh*, the data for which is given. The general data given is that of the vessels before their machinery was altered.

The *Raleigh*, under the old conditions, with Scotch boilers, never succeeded in working up to her full designed power of 7,500 I.H.P.

The wake coefficient corresponding to her trial speed is about what it should have been, so I have used it for computing the resultant propellers derived from the chart.

The propellers of the *Raleigh* plot, by their performance, as of only 67.3 per cent. efficiency, and above the maximum efficiency curve. As the value of the wake coefficient is correct, this poor showing can only be due to the fact that the propellers are too large.

From the speed curve of the *Raleigh* with 7,500 I.H.P. a speed of 20.11 knots would have been made.

Using the designed revolutions, 164, 7,500 I.H.P. and 20.11 knots with a wake coefficient of 1.08, a propeller is obtained of smaller diameter, less pitch, and less developed and projected areas than the original propellers, and plotting at 68.4 per cent.

efficiency, about equal to that of the *Drake* and the *Olympia*. For the possible full power of these engines, 10,000 I.H.P., the propellers fitted would have about the proper proportions.

*Detroit*, *Montgomery* and *Marblehead*.—These vessels are identical in design and requirements. The first two were built by the same contractor, and were fitted with screws identical in all respects except pitch, the blades of the *Detroit's* propellers being set at a slightly higher mean pitch than those of the *Montgomery*. The propellers of the *Marblehead* were of the same diameter as those of the others, but were of less pitch and greater surface.

Upon trial, the best results, as to speed, were obtained by the *Montgomery*, and her results will be taken as the data for the resultant screw.

Her wake coefficient, however, was too high for the speed developed and for the type of vessel, having a value of 1.107.

Assuming a wake coefficient of 1.08, with the data of the *Montgomery's* trial, a resultant screw is obtained which, while of the same diameter as the actual screws, has less pitch than those of the *Detroit* and the *Montgomery* and more than those of the *Marblehead*, while its surface, both developed and projected, exceeds all but that of the latter vessel.

The propellers of the *Montgomery* are, however, very satisfactory, and the probabilities are that the gain by any change would be very small.

*Columbia* and *Minneapolis*.—These vessels are similar in design and requirements, and are fitted with triple screws.

In plotting the position on the chart of the propellers of these vessels it is necessary to treat the center screws separately from the wing ones, as the conditions under which the wing and center propellers work are entirely different.

### THE CENTER PROPELLER.

The center propeller of the *Columbia* plots on the chart as inefficient and with a wake coefficient of only .94. In the case of the *Minneapolis*, with a screw identical with that of the *Columbia*, at the greater speed developed the efficiency of this propeller has risen to 69 per cent., and the wake-coefficient value to 1.099.

This case appears to be identical with that of the *Good Hope*, as shown on Plate II. As the wake, due to form of hull, in which the center screw works could never equal the velocity of wake in which the wing screws work, in place of using 1.08, the coefficient of the *Drake*, for the wake coefficient for the center propeller of these vessels we will use unity.

With this value of wake coefficient, and the performance data of the center propeller of the *Minneapolis*, we derive a propeller of larger diameter, less pitch and much greater surface than those fitted, and having an efficiency of 68.75 per cent.

This propeller, in addition to giving better results when all propellers were in use at full speed, would have been far more satisfactory when the center engine was being used alone than those fitted.

THE WING PROPELLERS.

The wing propellers of these two vessels were also identical, but the pitch of those of the *Minneapolis* was increased six inches over those of the *Columbia*. On trial the propellers of the *Minneapolis* plotted of slightly greater efficiency than those of her sister ship. The wake coefficients of both are high, much higher, in fact, than the fine form of these ships would justify.

Both vessels are as fine as vessels of the *Drake* class, if not finer, and we can reasonably expect the propellers to work in no greater wake than was met with in the *Drake*.

Adopting the wake coefficient of the *Drake*, 1.08, and using the trial data of the *Minneapolis*, we obtain a propeller plotting of equal efficiency and in the same locality on the chart as those of the *Drake*.

This propeller is a foot less in diameter than those fitted, has more area and less pitch than they, and for equal speeds will have considerably less slip.

*Olympia*.—The propellers of this vessel were designed with both axially and radially expanding pitch, the mean measured pitch as cast, and as set for trial, being 19 feet. What was the true pitch of the blades cannot be told, but it was probably not far from the mean measured pitch. This measured pitch has been used in plotting the propeller on the chart.

From the trial results of this vessel its propellers plot of 68.3 per cent. efficiency and in nearly the same location on the chart as those of the *Drake*, while the wake coefficient is very nearly that of the *Drake*. The value of the wake coefficient is 1.074.

For speed uuder cruising conditions the propellers of the *Olymyia* could hardly be improved upon. For trial-trip results a screw of less area and of higher pitch would have given greater efficiency.

In this case, as in that of all men-of-war, that which is required is a maximum of speed under cruising conditions with the maximum power of the engines, and in order to obtain this the propellers should be larger than are necessary for best trial results.

The argument against large surface screws has been advanced that if the screws have the necessary area for high speed efficiency they will be comparatively inefficient at cruising speeds.

The two prime requirements for a war vessel are fighting power and high speed, and every effort should be made to get the highest speed possible out of the design of hulls and engines. If efficiency of the propellers at high speed is sacrificed in order to obtain efficiency and economy at cruising speeds, we may deliberately have sacrificed the fraction of a knot of speed that would have put us in the fight or that would have allowed us to escape from an enemy of too great force.

### GUNBOATS.

*Machias* and *Castine*.—Of these two vessels I have taken the results of the *Machias'* trial for data in preference to those of the *Castine's*, because the boiler pressure used during the trial of the latter exceeded the allowed pressure. Also, the starboard counter of the *Castine* broke down during the trial, so that the average revolutions of the starboard engine were obtained by counting them at intervals and taking a mean of these counts. The *Machias*, on the other hand, was tried strictly under the requirements, and the average revolutions given are the average of the counters for the complete run.

The results of the *Machias'* trial plot her propeller as of 69 per cent. efficiency, but slightly below the maximum line, and give a

wake coefficient of 1.084. In the case of the *Castine*, the efficiency has fallen to 68.5 per cent. and the wake coefficient to about 1.00.

As the propellers of the *Machias* have reached their maximum efficiency at the speed realized, the efficiency will decrease with any further increase in speed or in power of engines, as is shown in the case of the *Castine*, unless the areas of the propellers be increased. The value of the wake coefficient may also be lowered slightly, with an increase of efficiency, by a proper dimensioning of the propeller.

Assuming a wake coefficient of 1.06, and that no greater diameter propeller can be used than those fitted, we obtain a resultant propeller plotting above the maximum line, but inside the 69 per cent. efficiency line.

This screw will stand the application of considerably higher power than was developed by the engines of the *Machias*, without any serious loss of efficiency, and will be better for high speeds at cruising draught than those fitted.

Upon comparing this propeller with the actual ones, we see that the latter had a small excess of pitch and lacked considerably in area.

*Nashville.*—This vessel is the only one of her class. Unfortunately, no progressive trials were made with her, so that the only point from which the wake coefficient value for the ship and propellers can be obtained is that obtained from her preliminary speed trial. As this value is so low for the speed and type of vessel, only 1.00, we will assume that with this vessel we have a case similar to that of the *Good Hope*.

If the similarity assumed exists, then the screw has practically broken down under this high power and speed, and the curve of wake coefficient at this point is rising rapidly towards the wake of cavitation. If this is the case, the propeller has too little surface, and that such is the case is further shown by the location on the chart in which it is plotted by its performance.

Assuming a wake coefficient value of 1.06, and designing the propeller to plot inside the 69 per cent. limit, using as a diameter that proposed by the Bureau of Steam Engineering, a resultant

screw is obtained. This screw, when compared with the actual propellers, shows that, provided our assumptions are correct, the trial propellers are too small in diameter and in surface, and have too large a pitch to give the best results in speed realized at high powers.

*Helena* and *Wilmington.*—These two vessels are of exceptional form, the draught being very small as compared with the beam. No progressive trials were held with them. The wake coefficients obtained from plotting the position of the propellers on the chart, as derived from their trial results, and the position in which these points plot, indicate that the propellers were radically wrong in their dimensions.

The propellers of these vessels, on account of the form of the hulls, operate under conditions which are practically intermediate between the conditions for twin propellers on the ordinary form of hull and the conditions for a single screw. The wake coefficient should neither be as high as for twin screws nor as low as for a single screw, the effect of form of hull on the velocity of the propeller race being less in the first case and greater in the second.

The wake coefficients of these two vessels derived from their trials are .854 for the *Helena* and .90 for the *Wilmington.* From the preceding paragraph we may expect to be able to increase the wake coefficients at least to unity, with a consequent gain in efficiency at the higher speeds.

Uusing this coefficient, we derive a screw of the same diameter as those used, it being assumed that no larger diameter can be fitted.

This resultant propeller has less pitch and about 30 per cent. more area than the actual propellers, and plots just inside the 69 per cent. efficiency line below the curve of maximum efficiency.

In order to plot it on, or a little above, the maximum curve, it would be necessary to increase the diameter in order to increase the surface. This should be done, if possible, for the blades of the resultant propeller given above will be abnormally wide, and an increased diameter would give us a narrower and better shaped blade and reduce the danger of blade interference.

PLATE VIII
U.S.S. Vicksburg
U.S.S. Newport.
U.S.T.B.D. Worden.
Indicated horse power.
Knots per hour.
Scale of M.
M. Vicksburg
M. Newport
M. Worden
Vicksburg
Newport
Worden
Knots per hour
Indicated horse power

*Annapolis*, *Newport*, *Princeton* and *Vicksburg*.—These vessels are similar in all respects, except in the case of the *Annapolis*, whose engines differ slightly from the other three, but are designed for the same power. Her engine stroke is a little shorter, but the piston speed is the same.

As all the engines worked below their designed piston speeds, I have used the trial results of the *Annapolis* as the data from which to calculate the resultant propeller, increasing the wake coefficient slightly above those found from the trial results, in order to increase the higher speed efficiencies.

These vessels are all fitted with single propellers working in a propeller race on which the effect of the form of hull is a maximum. In this case we could hardly increase the wake coefficient value for the maximum speed made to as high a value as for double screws without seriously decreasing the efficiency. That it can be increased to some extent and a slight amount of efficiency sacrificed at low speeds in order to gain at the higher is shown on Plate VIII, where are given the curves of I.H.P. and of wake coefficients for the *Newport* and the *Vicksburg*.

The propellers of these two vessels are identical in all respects but that of pitch, that of the *Newport* having slightly less than that of the *Vicksburg*. This small decrease in pitch and consequent increase in projected area has caused the *Newport* to be slightly less efficient at speeds up to 12 knots, when the difference between the efficiencies begins to decrease, and finally changes sign as the speed increases, the *Newport* then being the more efficient. The corresponding wake coefficients of the *Newport* have also been increased considerably above the values for the *Vicksburg*.

Choosing a wake coefficient of .975 and using the trial data of the *Annapolis*, we obtain a propeller of 69 per cent. efficiency, having the same diameter and pitch as that of the *Newport*, but 100 per cent. more area.

The location on the chart and the extremely low efficiency of the propellers of all of these vessels point directly to insufficient area.

The propellers are all four-bladed, and the blades cast solid with the hubs.

*Marietta* and *Wheeling*.—These two vessels are of the same design, and are fitted with propellers alike in all respects. Upon trial the propellers plotted at 68.75 per cent. and 68.9 per cent. efficiency respectively, while the corresponding wake coefficients are very high.

Fortunately, these vessels were both put through a series of progressive trials. Those of the *Wheeling* having been run in a fresh breeze at the higher speeds, I have discarded her trials at speeds above 10 knots, and have used those of the *Marietta* alone. The curves of wake coefficients and of I.H.P. are shown on Plate IX.

The curve of wake coefficients rises rapidly from the lowest speed run until the highest speed made, when it has reached an extremely high value for this type of vessel. This excessive value of wake coefficient is an indication of improper design of propeller for the speed made.

This high value of wake coefficient also tends to inefficiency and can be decreased by a proper form of propeller.

Assume a wake coefficient ratio of 1.10 for use. This is probably a little too high, but the error caused by its use will be small.

Using this coefficient and the trial results of the *Marietta*, we obtain a propeller of the same diameter as those fitted, of less pitch and of much greater area.

This propeller plots on the maximum line. It would be better for high speeds under cruising conditions to have given the propeller a little greater surface and a fraction less pitch. This change would have plotted it just above the maximum curve, and it would have reached its maximum efficiency in working against the increased resistance due to the increased draught at the cruising displacement.

*Bancroft*.—On Plate IX are also shown the curves of wake coefficients and of I.H.P. from the progressive trials of this vessel. It will be noticed that the curve of coefficients, after passing 10½ knots, rises rapidly until the end of the trials. At the highest

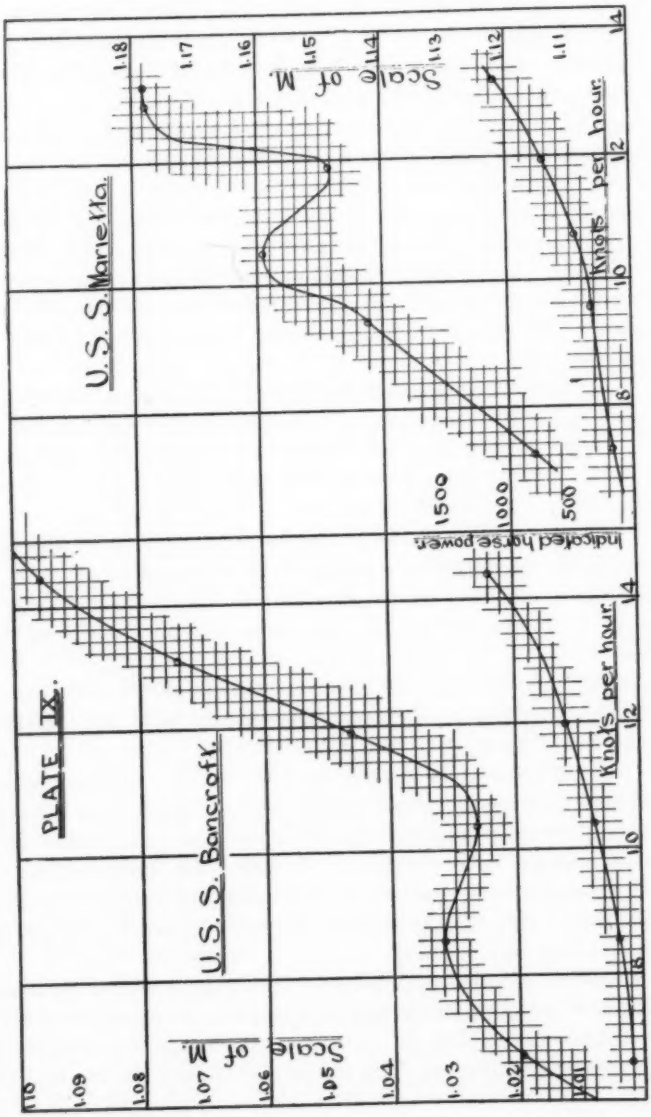


PLATE IX.
U.S.S. Boncroft.
U.S.S. Marietta.
Scale of M.
Indicated horse power.
Knots per hour.

speed realized the coefficient has a value of 1.095. By modifying the propeller this wake coefficient may be lowered to more nearly the proper value for vessels of the *Bancroft* type.

In the trials of this vessel it was found impossible to turn her propellers up to the designed speed of revolutions, and the I.H.P. fell short of the designed power.

From the curve of speed and I.H.P. we find that with the full designed power, and with propellers equal in efficiency at the higher speed to those fitted, a speed of 14.6 knots would have been made.

Using this speed, the designed I.H.P. and revolutions, and a wake coefficient of 1.06, a propeller is obtained which has the same diameter as those fitted, is less in pitch and developed surface, but greater in projected surface, while the efficiency remains the same. The indicated thrust per square foot of projected area has, at the same time, slightly decreased from that developed at the maximum speed and power of the trial.

MONITORS.

*Monterey.*—This vessel was designed for a speed of 16 knots with the engines developing 5,400 I.H.P. and making 150 revolutions. No curves of performance are available from which to give a fair estimate as to her speed if the full power designed had been realized.

The vessel had no progressive trials, and only succeeded in making a speed of 13.6 knots with an I.H.P. of 4,987 and 161.5 revolutions.

From this performance the propellers plot very low in efficiency, only 62 per cent., and below the maximum line, while the wake coefficient value is very high, 1.298, which is not justified by the form of hull. The high wake coefficient and the position of the propellers on the chart both indicate lack of area of the blades.

Assuming a wake coefficient of 1.04, which, by comparison with other vessels of nearly similar value of hull coefficients appears to be about the proper value, and using the trial data, we obtain a propeller of 67.1 per cent. efficiency.

The propellers fitted were only 10 feet 2 inches in diameter, but 11 feet propellers could have been fitted.

Using this latter diameter in order to obtain as much area as possible for the blades, we obtain a propeller having less pitch than the actual screws, 6.6 feet more developed area and 9 feet more projected area. These propellers would have very broad blades, and if any considerably higher efficiency is sought it would be necessary to still further increase the diameter of the screws.

Maximum efficiency at high speed could never be obtained with the piston speed and designed power on account of the impossibility of fitting a screw of sufficient diameter to properly carry the necessary surface.

*Arkansas*, *Florida*, *Nevada* and *Wyoming*.—These four monitors are alike in hull, designed power and revolutions of engines, and have each been built by different contractors. The propellers are different for each one of the four, but are close in designed pitch for three of them and in developed area for all.

Of the four, all have been tried at the present time, two of them having been given progressive trials. Unfortunately, that one of the four which gave the best performance on her preliminary trial was not allowed to make the progressive trials.

The *Arkansas* and the *Wyoming* were both given progressive trials, and on Plate VI are shown the curves of wake coefficients and of I.H.P. for both vessels.

The results of the trial at maximum speed for the *Wyoming's* propellers plot them as quite inefficient, while the location on the chart and the high value of the wake coefficient, 1.143, indicate lack of area. Comparison with the curve of wake coefficients of the *Arkansas* would also seem to indicate lack of diameter.

The results of the maximum speed run of the *Arkansas* plot her propellers as of 69 per cent. efficiency for the conditions, but also indicate slight want of area. The wake coefficient of this vessel is not particularly high, being only 1.089, but when compared with that of the *Nevada's* propellers, which gave the greatest speed for the least expenditure of power, this value is also high.

The wake coefficient of the *Nevada's* propellers works out at

1.033, while the propellers plot of equal efficiency at 13.04 knots with those of the *Arkansas* at 12.71 knots. They also plot below the maximum line, and indicate a small lack of area.

The *Florida*, whose propellers are the next in diameter and pitch to the *Wyoming*, made, on her trial, a speed of 12.4 knots, while developing 2,317 I.H.P. with the main engines. The wake coefficient corresponding to this performance is 1.09, while the efficiency is only 67.9 per cent.

The following table shows how the efficiencies of the propellers of these vessels have varied inversely with the wake coefficients.

| | | | |
|---|---|---|---|
| *Wyoming:* | Speed.....12.37; | I.H.P..... 2,811; | wake coefficient.....1.143 |
| *Florida:* | Speed.....12.4; | I.H.P.....2,317; | wake coefficient.....1.09 |
| *Arkansas:* | Speed.....12.71; | I.H.P.....2,190; | wake coefficient.....1.089 |
| *Nevada:* | Speed.....13.04; | I.H.P.....1,940; | wake coefficient.....1.033 |

Estimating from the trial results of the *Nevada* that these vessels could develop a speed of 13.98 knots with the designed power and revolutions, we will use these latter figures to obtain the proper screw. We will also assume a wake coefficient of 1.04.

Using this data, the propeller derived plots very little above the line of maximum efficiency. It is 9 feet in diameter, is of less pitch than the screws of the *Wyoming* and of the *Florida*, but of more than those of the other two vessels, while it exceeds the propellers of all in developed and projected areas. The indicated thrusts per square foot of developed and of projected areas work out at a slightly less value than those developed by the three vessels already tried.

HARBOR-DEFENSE RAM.

*Katahdin.*—This vessel had, at different times, three sets of propellers fitted to her. The first set was abandoned upon the first trial. The second set, given on the first line of the table for the *Katahdin*, was used for a series of propressive trials, and was then removed. Set No. 3, on second line of table, was then fitted, tried progressively, and used for the final trials.

The curves of wake coefficients are shown on Plate V, and discussed in showing the influence of diameter of propeller on wake.

The wake coefficient for No. 3 propeller is low, and the propeller plots at 69 per cent. efficiency. Its position on the chart, however, indicates lack of surface, as it plots below the maximum line.

Using the trial results for this propeller as data, and using the wake coefficient derived from these trial results, but giving the propeller sufficient area to plot on the maximum line of efficiency, we obtain a propeller having the same diameter, but much greater area, both developed and projected, and less pitch than those fitted, and have caused a considerable decrease in the indicated thrust per square foot of areas.

If better results are to be looked for with this vessel, they can not be expected with the present propellers, as they are entirely too small.

TORPEDO-BOAT DESTROYERS.

*Perry*, *Paul Jones*, *Freble*, *Bainbridge*, *Barry*, *Chauncey*, *Dale*, *Decatur* and *Stewart*.—The foregoing-named vessels, while varying slightly in their requirements for speed, are practically identical in hulls and machinery, and should all be capable of developing the same speed.

While progressive trials were held with all of these vessels, the only ones of which full data were taken during the official trials were the first three named, while full data was taken on the contractors' trials of the *Bainbridge*.

The effect on wake and on I.H.P. of the variation of surface on the propellers of the *Perry*, the *Paul Jones* and the *Preble* are shown on Pate IV, already discussed.

For the speed obtained by the *Preble*, her propellers were more efficient than those of the *Paul Jones* for the maximum speed made by that vessel, while the wake coefficients of the two at these two speeds were the same.

The wake coefficients for these vessels may probably be still further decreased and the efficiency increased by a properly designed screw, so we will assume a wake coefficient value of 1.16 as the proper one to use, and will design our propeller to give the same efficiency at the desired speed as that of the *Preble* at her maximum developed speed.

These vessels were all originally designed for 30 knots. From the I.H.P. curves of the *Paul Jones* it is seen that for this speed an I.H.P. of about 8,400 will be necessary. That the engines of these vessels are capable of developing this power is demonstrated by the results of the *Bainbridge* trials, where a total engine power of 8,450 I.H.P. was developed with the engines making 334.6 revolutions.

Using a wake coefficient of 1.16, speed 30 knots, I.H.P. 8,400 and 335 revolutions, a resultant propeller 7 feet 6 inches in diameter is obtained. This propeller has been designed to plot of the same efficiency as those of the *Preble*, as before stated.

It is of slightly greater diameter than those of the *Perry*, the *Paul Jones* and the *Preble;* has much greater developed and projected areas than the *Perry*, and slightly greater than the *Preble*, but less than the *Paul Jones*, and exceeds the three in pitch.

It is less in diameter than the propellers of the remainder of the vessels; exceeds in pitch those of the *Bainbridge*, the *Stewart*, the *Dale* and the *Decatur*, but is slightly exceeded in that dimension by the *Barry* and the *Chauncey*. It has less surface, both projected and developed, than the propellers of the *Bainbridge*, the *Barry*, the *Chauncey* and the *Stewart*, and more than those of the *Dale* and the *Decatur*.

It will be considerably lighter than the propellers of all the vessels except the *Perry's*, the *Preble's*, the *Dale's* and the *Decatur's*.

However, as in cruising condition the vessels are well loaded down, it would be wise to allow for the increased resistance due to this loading, and as there is no doubt of the ability of the engines of the vessels to work well above the designed power, increase the surface and slightly decrease the pitch. Also, as when propellers are worked up to their practical limit—that is, when they are on the verge of cavitating—vibration of the hull and machinery is liable to occur, an increase in surface would tend to reduce or to prevent this vibration. Such increase in surface would, however, further sacrifice efficiency.

*Truxtun*, *Whipple* and *Worden*.—These three vessels are of slightly different design from those just discussed. They are of

greater length and of greater ratio of length to beam, and are finer lined, making them easier to drive at the highest speed than the preceding vessels. While from the curve of speed and I.H.P. for the *Paul Jones* 8,400 I.H.P. is required for that vessel and her sisters, from the performance curve of the *Worden*, to obtain a speed of 30 knots, only 8,300 I.H.P. would be required for these vessels.

While complete data of speed, revolutions and I.H.P. were taken during the progressive trials of these three vessels, greater care was taken in obtaining this data for the *Worden* than for the other two, and on this account I have taken the results of her trials as a fair example of the performances of which these vessels are capable.

The design of these vessels called for a speed of 30 knots with the engines developing 8,300 I.H.P. while making 327 revolutions. The engines are of ample size for the designed power, and there is no doubt of their ability to develop it.

The trial results of the *Worden* gave a wake coefficient of 1.175 for a speed of vessel of 29.78 knots. By examination of Plate VIII it will be seen that at this speed the curve of wake coefficients shows no sign of an upward tendency, but shows us that at a still higher speed than 29.78 knots a lower coefficient can be expected.

Using the designed requirements and a wake coefficient of 1.16, the same as used for the first lot of destroyers discussed, and plotting the screws to be of equal efficiency with those of the *Preble*, we obtain a propeller 6 inches less in diameter than those fitted, having slightly less pitch, equal developed but less projected area.

This propeller will, however, be working close to the limit for cavitation, and it would probably be a matter of good judgment to increase the areas and still further decrease the pitch to a slight extent. Such a change would also, as stated before, tend to reduce vibrations of hull and machinery.

*Hopkins* and *Hull*.—Great trouble has been experienced with these two vessels in attempting to obtain the designed speed. They trim very badly, being well down by the stern, and the en-

gines have vibrated considerably. While designed for 29 knots, they have never reached that speed, the *Hull*, on her progressive trials, having made a speed just above 28 knots.

The results given in the tables are from the reports of a contractors' trial, and are presumed to be accurate.

From the plotted position of this propeller performance a wake coefficient of 1.19 is obtained. This value is not far from the wake coefficient values at maximum speed of the other destroyers; so that, judging by this similarity alone, one would suppose that these propellers were nearly the proper ones, and would say that the vessel could not make any greater speed with the power developed.

That this is not necessarily so is seen at once upon examination of Plate II, the curves of wake coefficients of the *Good Hope* and *Drake*. Here it is seen that at a speed of 22.8 knots the wake coefficients of the two sets of propellers are the same, yet the I.H.P. necessary for the *Drake* at that speed is much less than that required for the *Good Hope*. In fact, the *Good Hope's* propellers are very close to their limit of propulsion, while the *Drake's* hold on for over a knot more speed than was made by the *Good Hope*. The *Drake's* propellers, from the wake coefficient curve, appear to be able to take care of much greater power than the engines were capable of developing. On the other hand, while the powers developed by the engines of the two vessels were almost identical, the wake coefficient curve of the *Good Hope* indicates that the maximum limit of useful effect of her propellers has been reached and, probably, cavitation had begun. The vibration of the *Good Hope* at high speeds is also reported to have been heavy, a portion of this vibration undoubtedly being due to the cavitating of the screw. Practically the only difference between the screws of the *Good Hope* and *Drake* was in surface, as stated in the earlier part of this article.

Now, from reports received as to the behavior of the *Hull* on trial, from her bad trim and from the abnormally high power required to make the speed actually developed, we are justified in supposing that we have in the *Hull* a case exactly similar to that of the *Good Hope*.

Assume that with the power required for 28.2 knots, the speed made on trial, the *Hull* could make 29 knots with a properly designed propeller. We are justified in this assumption by the *Good Hope—Drake* results—as the increase asked for in the case of the *Hull* is considerably less than the percentage increase obtained in the known case.

With this speed, the developed power and revolutions, and with a wake coefficient of 1.12, as with this hull and trim the coefficient can hardly be raised to an equality with that of other vessels of the same class without too great a sacrifice of efficiency, a propeller is obtained of considerably greater area, but less pitch, than those fitted. In order to carry the great area this propeller is given a diameter of 8 feet. This propeller plots of 65.5 per cent. efficiency, equal to that of the *Paul Jones*, this sacrifice in efficiency being made in order to insure against increase in engine vibrations by the propeller action.

The present propellers are too small in all respects except that of pitch, where they are in excess.

TORPEDO BOATS.

*Ericsson.*—This vessel, after many trials, succeeded in standardizing at a maximum speed of 21.24 knots with the engines developing nearly their designed power, the vessel having been designed for 24 knots speed.

The results of the trial plot the propeller as being only 67.6 per cent. efficient and below the curve of maximum efficiency. This position, together with the low value of the wake coefficient, very low for a twin-screw vessel of such fine form, indicates too small surface of the screw. The shape of the curve, shown on Plate III, is very similar to that of the *Good Hope*, and at the highest speed made is rising rapidly.

The wake coefficient of the *Cushing*, which, in her general proportions, does not differ to any great extent from the *Ericsson*, is 1.075 for 22.5 knots. As this vessel made her speed without trouble, we will use her coefficient, or a little larger one, 1.08, for the *Ericsson*.

Using this coefficient and the trial data of the vessel, a resultant

screw of the same diameter and practically the same area, both developed and projected, as the actual screws is obtained. This propeller has, however, considerably more pitch than the actual screws, plots of 69 per cent. efficiency, and the resultant pressures per square foot of developed and projected areas are much reduced.

*Cushing*.—The results of the trials of this vessel have already been referred to. The wake coefficient does not appear extravagantly high for the type of vessel, but the efficiency is low, only 67.1 per cent. As, however, the surface of these propellers is as large as should be used with their diameter, and as it is assumed that no greater diameter can be fitted, it is doubtful whether her propellers could be improved.

*Foote*, *Rodgers* and *Winslow*.—Progressive trials were run with only one of these vessels, the *Rodgers*, and the results of her trial are used to obtain the resultant propeller.

From the results of her trials a curve of wake coefficients and I.H.P. are laid down on Plate III. The curve of wake coefficients is abnormally high. It should, at its highest, be no greater than that for destroyers at their top speed. By comparison with the *Craven's* curve, shown on Plate X, it is doubtful if its value for the highest trial speed should exceed 1.11.

In computing the resultant propeller, however, I have given the actual screws the benefit of the doubt, and have used a wake coefficient of 1.16, which is probably too high.

The propeller obtained differs from those fitted in having larger diameter, less pitch, slightly less developed surface and less projected surface, while the thrusts per square foot of the areas remain about the same. As the expected speed is to exceed the speed obtained on trial, these thrusts are those corresponding to this higher speed. Where the speeds are the same, then these thrusts will occur when the vessel has been loaded down sufficiently to increase the resistance to the point where the power generated on trial will be required for the trial speed with the new propellers.

*Dahlgren* and *Craven*.—Of these two vessels the record shows that only one, the *Craven*, was given a series of progressive trials.

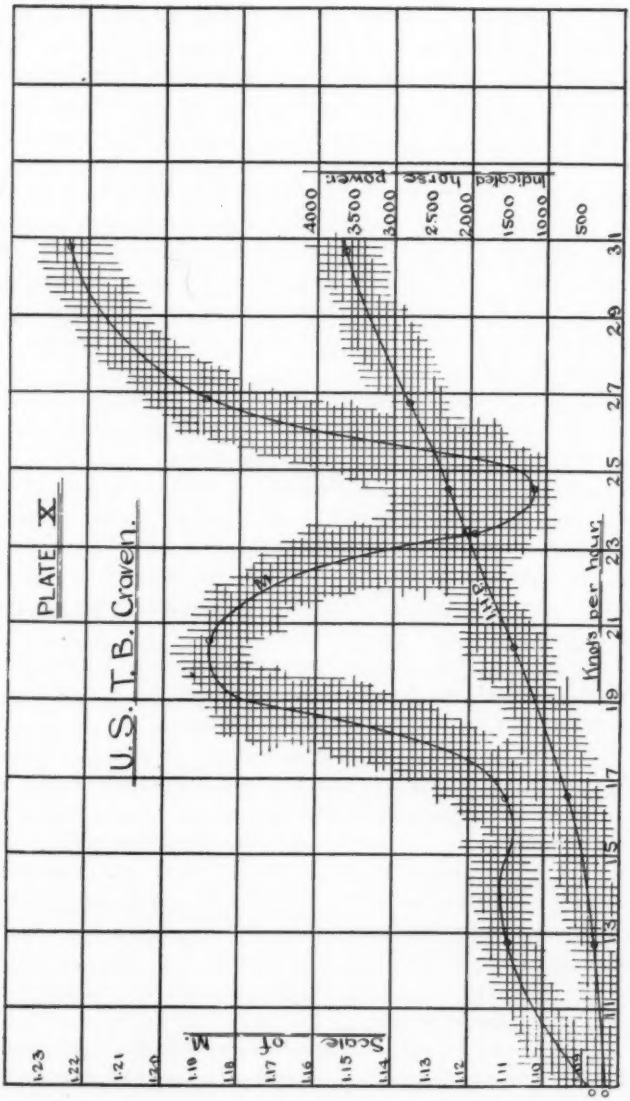


PLATE X
U.S. T.B. Craven.
Indicated horse power.
Knots per hour.
Scale of Models

These trials were contractors' trials, and it is impossible to say how carefully they were conducted. For lack of other data, however, it is necessary to use the results obtained from them.

The curves of wake coefficients and of I.H.P. are shown on Plate X. By examining these curves it would seem as if these propellers could hardly be improved, and it is very doubtful if any change would be for the better.

At the highest speed made, 30.74 knots, the wake coefficient shows no signs of a tendency to a sudden rise, and the I.H.P. curve is also steady in its increase, its ratio of increase with the speed appearing to be decreasing rather than increasing.

The wake coefficient at this maximum speed has reached a value of 1.22. It may be possible to make changes in the propeller that will decrease this coefficient to some extent with consequent gain in economy.

Use a wake coefficient of 1.16 and the trial results to obtain the resultant screw, and we obtain a propeller differing, practically, in only one point from the actual screws. The pitch is a little less and the thrusts per square foot of areas are slightly increased, these thrusts being for a higher speed, however, than that realized on trial.

As stated before, to change the propellers of these two vessels would be of doubtful value, and the gain in results would probably not pay for the change.

*Bagley*, *Barney* and *Biddle*.—The curves of I.H.P. and of wake coefficients for these vessels, obtained from trials of the *Barney*, are shown on Plate XI. These trials were made under poor conditions, the bottom of the vessel and her propellers being very foul at the time. The evil effect of this foulness, in decreasing the efficiency and raising the value of the wake, was shown on the Government progressive trials, when with an I.H.P. of 3,910, a speed of 29.04 knots was attained with a value of wake coefficient of only 1.17, against 27.1 knots, 4,100 I.H.P., and a wake coefficient of 1.14 on the earlier trials.

These propellers are probably as satisfactory as could be fitted. If any improvement could be made, it must be made by proportioning the propellers so as to reduce the value of the wake factor.

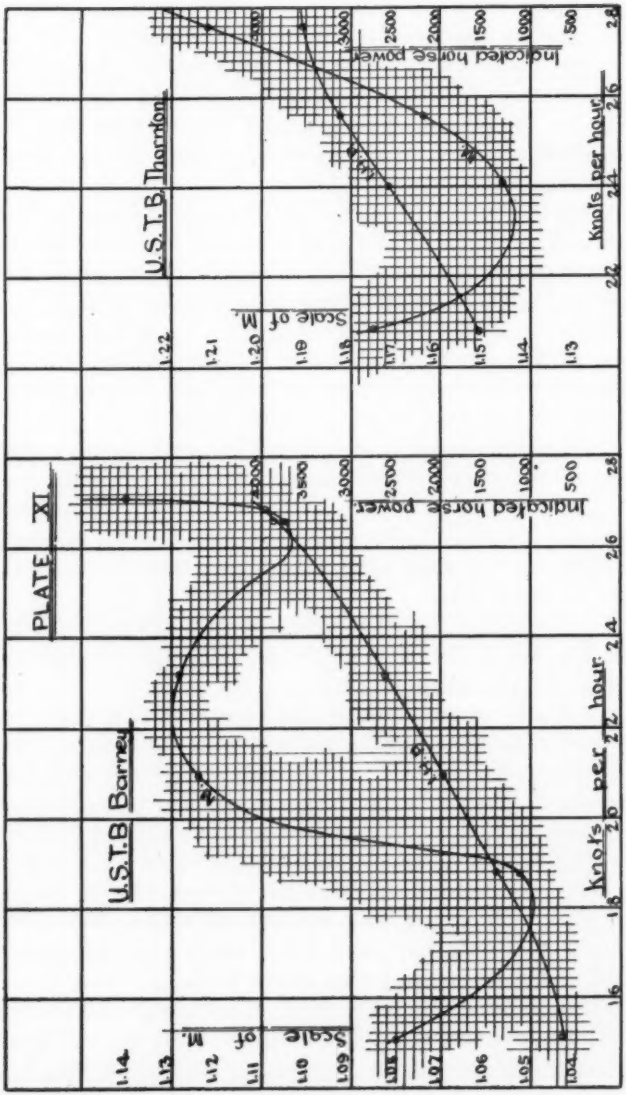


PLATE XI.
U.S.T.B. Barney
U.S.T.B. Thornton
Scale of M.
Indicated horse power
Knots per hour

Using a wake factor of 1.16 and the Government trial results, a propeller is obtained which differs only in pitch from those fitted. The pitch is a little greater than that of the actual propellers, and would cause a reduction in the thrusts, and thus render the propellers capable of higher speed than was made, with an increase in efficiency at this increased speed.

*Shubrick*, *Stockton* and *Thornton*.—On Plate XI are also shown the curves of I.H.P. and of wake coefficients as obtained from the progressive trial results of the *Thornton*. From an inspection of the wake coefficient curve it appears that these propellers had very nearly attained their limit of propulsive efficiency. Although the I.H.P. curve shows no sudden break upwards at the higher speeds, the wake coefficient value is increasing very rapidly.

These screws are efficient, but a slight improvement might be made by designing them to produce a lower coefficient, no higher than that of the destroyers, 1.16.

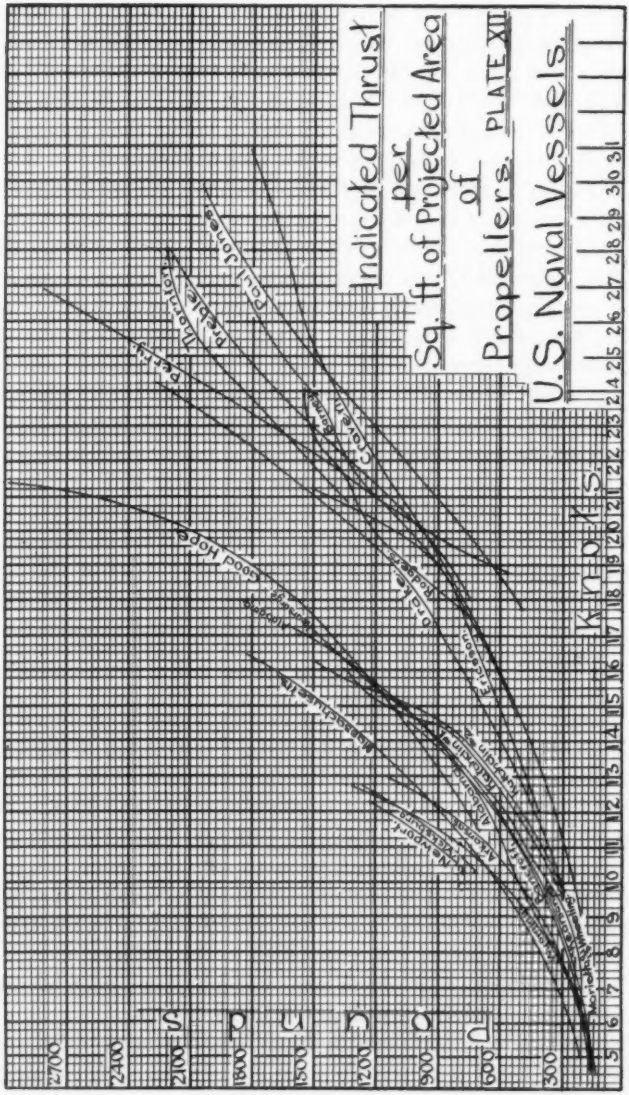
Using this value of the coefficient and the trial results of the *Thornton*, we obtain a propeller identical with the actual ones in all but surface, both developed and projected, where there is a slight increase. This increase reduces the amount of the indicated thrusts per square foot of both developed and projected areas, and should be of value in producing a higher speed than that realized.

## CONCLUSION.

In designing the propellers for vessels of the U. S. Navy the Bureau of Steam Engineering has always considered that, as the contractors were alone responsible for the speed of vessels, they should be given a free hand in the choice of propellers. The Bureau, while not always agreeing with the contractors on this question, has usually allowed them to use the propellers proposed by them. But where the difference between the screws proposed and the Bureau screw has been considerable, the attention of the contractors has been called to this difference.

In this latter case, however, the contractor has been allowed to fit propellers of his own design if he so desired.

While I have undertaken the foregoing work with much hesitation, I believe the results obtained are of value. By running a


Indicated Thrust per Sq. ft. of Projected Area of Propellers. PLATE XII
U.S. Naval Vessels.
Knots per H.
2700
2400
2100
1800
1500
1200
900
600
300
S
P
U
T
Q
D
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

series of progressive trials, and taking full data from which curves of I.H.P. and wake coefficients are laid down, an infallible indication of the performance of the propellers can be obtained and a perfect guide supplied to assist in judging as to the desirability of retaining or of rejecting the propellers with which the trials were made. In this connection it should be thoroughly borne in mind that even should a propeller plot, by its trial data, as of maximum efficiency, this is not necessarily the true efficiency of the screw.

The true efficiency is only obtained when the proper wake coefficient for the form of hull driven is found to exist in the value of $C_R$ corresponding to this plotted point.

In deriving the proposed propellers in the following tables, I have used as wake coefficients those values which I consider are shown to be the most nearly correct by actual performances.

These values can, of course, be only approximations until our knowledge of them is increased by further trials.

On Plate XII are shown curves of indicated thrust per square foot of projected area, compiled from progressive trial results of several vessels.

SCREW PROPELLERS

| Reference No. | Name of vessel. | Displacement. | Dimensions. | | | | | Area immersed midship sect. | Hull coefficients. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Length L.W.L. | Beam. | Draft, for'd. | Draft, aft. | Draft, mean. | | Cyl. | Extr. dim. | Midship sec't. | L.W. plane. |
| | | | *ft. ins.* | *ft. ins.* | *ft. ins.* | *ft. ins.* | *ft. ins.* | *sq. ft.* | | | | |
| 1 | *Indiana* | 10,225 | 348 0 | 69 3 | 24 0 | 24 0 | 23.88 | 1,545 | .668 | .622 | .931 | .746 |
| | | 10,225 | ... | ... | 23.69 | 24.06 | 23.87 | ... | Wa | ke co | eff. | 1.179 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.04 |
| 2 | *Massachusetts* | 10,225 | 348 0 | 69 3 | 24 0 | 24 0 | 23.88 | 1,545 | .668 | .622 | .931 | .746 |
| | | 10,265 | ... | ... | 23.79 | 24.38 | 24.08 | ... | Wa | ke co | eff. | 1.232 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.04 |
| 3 | *Oregon* | 10,225 | 348 1½ | 69 3 | 24 0 | 24 0 | 23.88 | 1,545 | .668 | .622 | .931 | .746 |
| | | 10,250 | ... | ... | 24 0 | 24 0 | 24 0 | ... | Wa | ke co | eff. | 1 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.04 |
| 4 | *Iowa* | 11,340 | 360 0 | 72 2½ | ... | ... | 24 0 | 1,635 | .668 | .630 | .944 | .733 |
| | | 11,363 | ... | ... | 23 8½ | 24 4½ | 24 0½ | ... | Wa | ke co | eff. | 1.102 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.04 |
| 5 | *Maine* | 5,500 | 318 0 | 57 0 | ... | ... | 18 6 | 906 | .668 | .574 | .859 | .747 |
| | (old) | 5,500 | ... | ... | 18 0 | 19 0 | 18 6 | ... | Wa | ke co | eff. | 1.09 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.09 |
| 6 | *Texas* | 6,300 | 301 4 | 64 | ... | ... | 22 6 | 1,305 | .562 | .555 | .906 | .657 |
| | | 6,320 | ... | ... | 21 5 | 23 10½ | 22 7½ | ... | Wa | ke co | eff. | 1.13 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.07 |
| 7 | *Kentucky* | 11,500 | 368 1½ | 72 2½ | 23 5 | 23 5 | 23 5 | 1,618 | .681 | .643 | .957 | .757 |
| | | 11,538 | ... | ... | 23 2½ | 23 9½ | 23 5½ | ... | Wa | ke co | eff. | 1.025 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.04 |
| 8 | *Kearsarge* | 11,500 | 368 1½ | 72 2½ | 23 5 | 23 5 | 23 5 | 1,618 | .681 | .643 | .957 | .757 |
| | | 11,550 | ... | ... | 23 3 | 23 9 | 23 6 | ... | Wa | ke co | eff. | 1.024 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.04 |
| 9 | *Illinois* | 11,500 | 368 1½ | 72 2½ | 23 5 | 23 5 | 23 5 | 1,618 | .682 | .644 | .957 | .759 |
| | | 11,540 | ... | ... | 23 9 | 24 3 | 24 0 | ... | Wa | ke co | eff. | 1.047 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.04 |
| 10 | *Alabama* | 11,500 | 368 0 | 72 2½ | 23 5 | 23 5 | 23 5 | 1,610 | 683 | .637 | .948 | .756 |
| | | 11,562 | ... | ... | 23 6 | 23 10 | 23 8 | ... | Wa | ke co | eff. | 1.002 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.04 |
| 11 | *Wisconsin* | 11,500 | 368 0 | 72 2½ | 23 5 | 23 5 | 23 5 | 1,619.6 | .682 | .644 | .957 | .759 |
| | | 11,500 | ... | ... | 23 6 | 23 6 | 23 6 | ... | Wa | ke co | eff. | 1 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.04 |
| 12 | *Maine* | 12,500 | 388 0 | 72 2½ | ... | ... | 23 6 | 1,606 | .691 | .654 | .946 | .759 |
| | (new) | 12,804 | ... | ... | 23 9 | 24 3 | 24 0 | ... | Wa | ke co | eff. | 1.125 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.04 |
| 13 | *Missouri* | 12,230 | 388 0 | 72 2½ | ... | ... | 23 6 | 1,606 | .687 | .650 | .946 | .759 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.04 |
| 14 | *Ohio* | 12,440 | 388 0 | 72 2½ | ... | ... | 23 6 | 1,606 | .698 | .661 | .946 | .759 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.04 |
| 15 | *Georgia* | 14,600 | 435 0 | 76 2½ | ... | ... | 23 9 | 1,730 | .679 | .656 | .946 | .772 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.04 |

*a*. Trial results.....*b*. Proposed screw.....*c*. Blades set as cast.....*d*. Blades cast for 15 feet 9 inches pitch, true screw.....*e*. Pitch axially expanding.....*f*. True screw.....
*g*. Speed given is probably too high an estimated allowance of 1.5 knots having been taken

OF U. S. NAVAL VESSELS.

| Performance. | | | Propellers. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Speed. | Revs. | I.H.P. | Number. | Blades. | D. | P. | $\frac{P}{D}$ | Hel. area. | Proj. area. | $\frac{\text{Hel. area}}{\text{Disc. area}}$ | App. slip. | Effic. | Ind. thrust per sq. ft. Hel. area. | Ind. thrust per sq. ft. Proj. area. | Remarks. |
| *knots.* | | | | | *ft. ins.* | *ft.* | | | | | | | | | |
| 15 | 128 | 9,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 15.55 | 131 | 9,498 | .. | .. | 15 6 | 16 | 1.03 | 53.86 | 45.24 | .285 | 24.85 | 69 | 1,388 | 1,653 | *a,d.* |
| 17.2 | 132 | 10,890 | .. | .. | 15 6 | 15.19 | .98 | 75.5 | 63.4 | .4 | 13.07 | 69 | 1,183 | 1,409 | *b.* |
| 15 | 128 | 9,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 16.21 | 132.6 | 10,128 | .. | .. | 15 6 | 16 | 1.03 | 53.86 | 45.24 | .285 | 22.64 | 69 | 1,444 | 1,719 | *a,d.* |
| 17.2 | 132 | 10,890 | .. | .. | 15 6 | 15.19 | .98 | 75.5 | 63 4 | .4 | 13.07 | 69 | 1,183 | 1,409 | *b.* |
| 15 | 128 | 9,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 16.79 | 128.25 | 10,890 | .. | .. | 15 0 | 15.5 | 1.03 | 66 | 55.4 | .373 | 14.33 | 68.4 | 1,506 | 1,794 | *a,e,c.* |
| 17.2 | 132 | 10,890 | .. | .. | 15 6 | 15.19 | .98 | 75.5 | 63.4 | .4 | 13.07 | 69 | 1,183 | 1,409 | *b.* |
| 16 | 112.5 | 11,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 17.09 | 109.56 | 11,835 | .. | .. | 16 6 | 19.5 | 1.18 | 75.74 | 66 | .354 | 20.93 | 69 | 1,207 | 1,524 | *a,f,c.* |
| 17.09 | 109.56 | 11,835 | .. | .. | 16 6 | 18.65 | 1.13 | 85.5 | 69 | .4 | 15.18 | 69 | 1,119 | 1,385 | *b.* |
| 17 | 132 | 9,000 | 2 | 4 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 17.45 | 124.13 | 9,172 | .. | .. | 14 6½ | 16 08 | 1.108 | 65 5 | 54 8 | .4 | 11.51 | 69 | 1,156 | 1,381 | *a,g.* |
| 17.45 | 124 13 | 9,172 | .. | .. | 14 6½ | 16.08 | 1.109 | 65.5 | 54.8 | .4 | 11.51 | 69 | 1,156 | 1,381 | *b.* |
| 17 | 123 | 8,600 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 17.8 | 125 25 | 8,423 | .. | .. | 14 6½ | 17.33 | 1 19 | 66 | 52.6 | .4 | 16.9 | 68.3 | 955 | 1,200 | *a,f,c.* |
| 17.8 | 125.25 | 8,423 | .. | .. | 14 6½ | 16.82 | 1.16 | 59.44 | 47.5 | .360 | 14.4 | 69 | 1,110 | 1,389 | *b.* |
| 16 | 120 | 10,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 16.897 | 114 | 12,082 | .. | .. | 16 9 | 17.25 | 1.03 | 84.2 | 69.2 | .382 | 12.93 | 69 | 1,170 | 1,424 | *a,f,h.* |
| 17.45 | 117.9 | 12,647 | .. | .. | 16 9 | 17.25 | 1.03 | 88.2 | 70 34 | .4 | 13.12 | 69 | 1,219 | 1,529 | *b,i.* |
| 16 | 120 | 10.000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 16.816 | 114.05 | 11,674 | .. | .. | 16 9 | 17.25 | 1.03 | 84.2 | 69.2 | .382 | 13.11 | 69 | 1,151 | 1,415 | *a,f,h.* |
| 17 45 | 117.9 | 12,647 | .. | .. | 16 9 | 17 25 | 1.03 | 88.2 | 70.34 | .4 | 13.12 | 69 | 1,219 | 1,529 | *b,i.* |
| 16 | 120 | 10,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 17 45 | 117.9 | 12,647 | .. | .. | 16 9 | 17.25 | 1.03 | 84.2 | 69.2 | .382 | 13.12 | 69 | 1,277 | 1,554 | *a,f,h.* |
| 17.45 | 117.9 | 12,647 | .. | .. | 16 9 | 17.25 | 1.03 | 88.2 | 70.34 | .4 | 13.12 | 69 | 1,219 | 1,529 | *b.* |
| 16 | 120 | 10,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 17.013 | 114 65 | 11,073 | .. | .. | 16 0 | 17.25 | 1.09 | 76 | 62 | .378 | 14.07 | 68.8 | 1,198 | 1,452 | *a,f,c.* |
| 17.45 | 117.9 | 12 647 | .. | .. | 16 9 | 17.25 | 1.03 | 88.2 | 70 34 | .4 | 13.12 | 69 | 1,219 | 1,529 | *b,i.* |
| 16 | 120 | 10,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 17 17 | 119.2 | 12,322 | .. | .. | 15 6 | 17.25 | 1.13 | 68 | 57 | .360 | 16.68 | 67.6 | 1,433 | 1,710 | *a,f,c.* |
| 17.45 | 117.9 | 12,647 | .. | .. | 16 9 | 17.25 | 1.03 | 88.2 | 70.34 | .4 | 13.12 | 69 | 1,219 | 1,529 | *b,i.* |
| 18 | 126 | 16,000 | 2 | 3 | ... | ... | .. | ... | ... | ... | ... | ... | ... | ... | |
| 18 | 127.91 | 15,222 | .. | .. | 16 0 | 18 | 1.25 | 79 | 63 | .393 | 20.7 | 69 | 1,381 | 1,732 | *a,f,h.* |
| 18 5 | 126 | 16,000 | .. | .. | 17 0 | 17.17 | 1.01 | 90.8 | 75.7 | .4 | 13.34 | 69 | 1,344 | 1,613 | *b.* |
| 18 | 120 | 16,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 17 0 | 17.75 | 1.044 | 73.7 | 62.8 | .324 | 14.8 | ... | ... | ... | *a,f.* |
| 18.5 | 126 | 16,000 | .. | .. | 17 0 | 17 17 | 1.01 | 90.8 | 75.7 | .4 | 13.34 | 69 | 1,344 | 1,613 | *b,i.* |
| 18 | 120 | 15,100 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 15 6 | 17 5 | 1.13 | 68 | 57 | .36 | 17.7 | ... | ... | ... | *a,f.* |
| 18 5 | 126 | 16,000 | .. | .. | 17 0 | 17.17 | 1.01 | 90.8 | 75.7 | .4 | 13.34 | 69 | 1,344 | 1,613 | *b,i.* |
| 19 | 120 | 19,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 18 0 | 19 | 1.055 | 95.6 | 79.12 | .376 | ... | ... | ... | ... | |
| 19 | 120 | 19,000 | .. | .. | 17 9 | 18.58 | 1.045 | 99 | 81.8 | .4 | 13.5 | 69 | 1,424 | 1,723 | *b.* |

for headwind and tide.....*h.* Blades cast for 17-foot pitch.....*i.* From *Illinois'* performance.
*h.* Blades cast for 19-foot pitch.....*l.* From new *Maine's* curve.

SCREW PROPELLERS

| Reference No. | Name of vessel. | Displacement. | Dimensions. | | | | | Area immersed midship sect. | Hull coefficients. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Length L.W.L. | Beam. | Draft, for'd. | Draft, aft. | Draft, mean. | | Cyl. | Extr. dim. | Mid-ship sec't. | L.W. plane. |
| | | | *ft. ins.* | *ft. ins.* | *ft. ins.* | *ft. ins.* | *ft. ins* | *sq. ft.* | | | | |
| 16 | *Rhode Island*... | 14,600 | 435 0 | 76 2½ | ... | ... | 23 9 | 1,730 | .679 | .656 | .946 | .772 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | Wake co | eff. | ... |
| | | ... | ... | ... | ... | ... | ... | ... | | | | 1.04 |
| 17 | *New Jersey*..... | 14,600 | 435 0 | 76 2½ | ... | ... | 23 9 | 1,730 | .679 | .656 | .946 | .772 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | Wake co | eff. | ... |
| | | ... | ... | ... | ... | ... | ... | ... | | | | 1.04 |
| 18 | *Nebraska*..... | 14,600 | 435 0 | 76 2½ | ... | ... | 23 9 | 1,730 | .679 | .656 | .946 | .772 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | Wake co | eff. | ... |
| | | ... | ... | ... | ... | ... | ... | ... | | | | 1.04 |
| 19 | *Virginia*..... | 14,600 | 435 0 | 76 2½ | ... | ... | 23 9 | 1,730 | .679 | .656 | .946 | .772 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | Wake co | eff. | ... |
| | | ... | ... | ... | ... | ... | ... | ... | | | | 1.04 |
| 20 | *Connecticut*..... | 16,000 | 450 0 | 76 10 | ... | ... | 24 6 | 1,809 | .688 | .660 | .961 | .767 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | Wake co | eff. | ... |
| | | ... | ... | ... | ... | ... | ... | ... | | | | 1.04 |
| 21 | *Louisiana*..... | 16,000 | 450 0 | 76 10 | ... | ... | 24 6 | 1,809 | .688 | .660 | .961 | .767 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | Wake co | eff. | ... |
| | | ... | ... | ... | ... | ... | ... | ... | | | | 1.04 |
| 22 | *New York*..... | 8,100 | 380 0 | 64 3 | ... | ... | 24 0 | 1,350 | .540 | .509 | .975 | .679 |
| | | 8,480 | ... | ... | 21 9 | 26 0½ | 23 10½ | ... | | Wake co | eff. | 1.284 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.08 |
| 23 | *Brooklyn*..... | 8,150 | 400 6 | 64 8½ | ... | ... | 24 0 | 1,225 | .585 | .520 | .881 | .673 |
| | | 8,150 | ... | ... | 21 6 | 22 3 | 21 10½ | ... | | Wake co | eff. | 1.136 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.08 |
| 24 | *Pennsylvania*... | 13,400 | 502 0 | 69 6½ | ... | ... | 24 1 | 1,596.6 | .585 | .558 | .954 | .696 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | Wake co | eff. | ... |
| | | ... | ... | ... | ... | ... | ... | ... | | | | 1.08 |
| 25 | *Colorado*..... | 13,400 | 502 0 | 69 6½ | ... | ... | 24 1 | 1,596.6 | .585 | .558 | .954 | .696 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | Wake co | eff. | ... |
| | | ... | ... | ... | ... | ... | ... | ... | | | | 1.08 |
| 26 | *West Virginia*.. | 13,400 | 502 0 | 69 6½ | ... | ... | 24 1 | 1,596.6 | .585 | .558 | .954 | .696 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | Wake co | eff. | ... |
| | | ... | ... | ... | ... | ... | ... | ... | | | | 1.08 |
| 27 | *Maryland*..... | 13,400 | 502 0 | 69 6½ | ... | ... | 24 1 | 1,596.6 | .585 | .558 | 954 | .696 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | Wake co | eff. | ... |
| | | ... | ... | ... | ... | ... | ... | ... | | | | 1.08 |
| 28 | *California*..... | 13,400 | 502 0 | 69 6½ | ... | ... | 24 1 | 1,596.6 | .585 | .558 | .954 | .696 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | Wake co | eff. | ... |
| | | ... | ... | ... | ... | ... | ... | ... | | | | 1.08 |
| 29 | *South Dakota*... | 13,400 | 502 0 | 69 6½ | ... | ... | 24 1 | 1,596.6 | .585 | .558 | .954 | .696 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | Wake co | eff. | ... |
| | | ... | ... | ... | ... | ... | ... | ... | | | | 1.08 |
| 30 | *Washington*.... | 14,500 | 502 0 | 72 10½ | ... | ... | 25 0 | 1,732 | .539 | .554 | .950 | .686 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | Wake co | eff. | ... |
| | | ... | ... | ... | ... | ... | ... | ... | | | | 1.08 |

*a*. Trial results.....*b*. Proposed screw.....*f*. True screw.

OF U. S. NAVAL VESSELS.

| Performance. | | | Propellers. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Speed. | Revs. | I.H.P. | Number. | Blades. | D. | P. | $\frac{P}{D}$ | Hel. area. | Proj. area. | $\frac{\text{Hel. area}}{\text{Disc. area}}$ | App. slip. | Effic. | Ind. thrust per sq. ft. Hel. area. | Ind. thrust per sq. ft. Proj. area. | Remarks. |
| *knots.* | | | | | *ft. ins.* | *ft.* | | | | | | | | | |
| 19 | 120 | 19,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 19 | 120 | 19,000 | .. | .. | 17 9 | 18.58 | 1.045 | 99 | 81.8 | .4 | 13.5 | 69 | 1,424 | 1,723 | |
| 19 | 120 | 19,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 19 | 120 | 19,000 | .. | .. | 17 9 | 18 58 | 1.045 | 99 | 81.8 | .4 | 13.5 | 69 | 1,424 | 1,723 | |
| 19 | 120 | 19,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 17 9 | 19 | 1.07 | 89.6 | 73.4 | .362 | ... | ... | ... | ... | *f.* |
| 19 | 120 | 19,000 | .. | .. | 17 9 | 18.58 | 1.045 | 99 | 81.8 | .4 | 13.5 | 69 | 1,424 | 1,723 | |
| 19 | 120 | 19,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 19 | 120 | 19,000 | .. | .. | 17 9 | 18.58 | 1.045 | 99 | 81.8 | .4 | 13.5 | 69 | 1,424 | 1,723 | |
| 18 | 120 | 16,500 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 17 9 | 17.4 | .98 | 99 | 83.2 | .4 | ... | ... | ... | ... | *f.* |
| 18 | 120 | 16,500 | .. | .. | 17 9 | 17.4 | .98 | 99 | 83.2 | .4 | 12.64 | 69 | 1,317 | 1,566 | |
| 18 | 120 | 16,500 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 18 | 120 | 16,500 | .. | .. | 17 9 | 17.4 | .98 | 99 | 83.2 | .4 | 12.64 | 69 | 1,317 | 1,566 | |
| 20 | 129 | 16,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 21 | 134.82 | 16,947 | .. | .. | 16 0 | 21 | 1.425 | 69.09 | 56 6 | .344 | 24.48 | 66.6 | 1,378 | 1,648 | *a.f.i.* |
| 21.4 | 136.5 | 18,248 | .. | .. | 16 6 | 18.32 | 1.11 | 85.82 | 69 8 | .4 | 13.3 | 68.5 | 1,403 | 1,726 | *b.* |
| 20 | 129 | 16,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 21 9 | 130.5 | 18,248 | .. | .. | 16 6 | 20 | 1.21 | 75.74 | 59.5 | .354 | 18.67 | 67 | 1,456 | 1,854 | *a.f.k.* |
| 21.9 | 136.5 | 18,248 | .. | .. | 16 6 | 18 81 | 1.14 | 81.25 | 65.2 | .38 | 13.5 | 68.5 | 1,443 | 1,797 | *b.* |
| 22 | 120 | 23,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 18 0 | 22 | 1.22 | 92 | 74 | .361 | 15.5 | ... | 1,562 | 1,929 | *f.* |
| ... | ... | ... | .. | .. | 18 0 | 21.42 | 1.19 | 102.8 | 81.2 | .4 | 13.27 | 68.5 | 1,436 | 1,818 | |
| 22 | 120 | 23,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 18 0 | 22 | 1.22 | 92 | 74 | .361 | 15.5 | ... | 1,562 | 1,929 | *f.* |
| ... | ... | ... | .. | .. | 18 0 | 21.42 | 1.19 | 102.8 | 81 2 | .4 | 13.27 | 68.5 | 1,436 | 1,818 | |
| 22 | 120 | 23,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 17 6 | 22 | 1.26 | 83.7 | 67.5 | .348 | 15.5 | ... | 1,717 | 2,130 | |
| ... | ... | ... | .. | .. | 18 0 | 21.42 | 1.19 | 102.8 | 81.2 | .4 | 13.27 | 68.5 | 1,436 | 1,818 | |
| 22 | 120 | 23,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 17 6 | 22 | 1.26 | 83.7 | 67.5 | .348 | 15.5 | ... | 1,717 | 2,130 | |
| ... | ... | ... | .. | .. | 18 0 | 21.42 | 1.19 | 102.8 | 81.2 | .4 | 13.27 | 68.5 | 1,436 | 1,818 | |
| 22 | 120 | 23,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 18 0 | 21.42 | 1.19 | 102.8 | 81.2 | .4 | 13.27 | 68.5 | 1,436 | 1,818 | |
| 22 | 120 | 23,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 18 0 | 21.42 | 1.19 | 102.8 | 81.2 | .4 | 13.27 | 68.5 | 1,436 | 1,818 | |
| 22 | 120 | 23,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 18 0 | 21.42 | 1.19 | 102.8 | 81.2 | .4 | 13.27 | 68.5 | 1,436 | 1,818 | |

*i.* Blades cast for 20-foot pitch.....*k.* Blades cast for 20 feet 9 inches pitch.

SCREW PROPELLERS

| Reference No. | Name of vessel. | Displacement. | Dimensions. | | | | | Area immersed midship sect. | Hull coefficients. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Length L.W.L. | Beam. | Draft, for'd. | Draft, aft. | Draft, mean. | | Cyl. | Extr. dim. | Mid-ship sec't. | L.W. plane. |
| | | | *ft. ins.* | *ft ins.* | *ft. ins.* | *ft. ins.* | *ft. ins* | *sq. ft.* | | | | |
| 31 | *Tennessee* | 14,500 | 502 0 | 72 10½ | ... | ... | 25 0 | 1,732 | .539 | .554 | .950 | .686 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wake co | | eff. | 1.08 |
| 32 | *Baltimore* | 4,400 | 315 0 | 48 6 | ... | ... | 20 0 | 816.6 | .597 | .515 | .842 | .712 |
| | | 4,391 | ... | ... | 18 2 | 21 7 | 19 6½ | ... | Wake co | | eff. | 1.064 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.064 |
| 33 | *Philadelphia* | 4,300 | 327 6 | 48 6½ | ... | ... | 19 6 | 815 | .568 | .515 | .861 | .712 |
| | | 4,325 | ... | ... | 16 10 | 21 7 | 19 2½ | ... | Wake co | | eff. | 1.15 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.07 |
| 34 | *Newark* | 4,098 | 310 10 | 49 2 | ... | ... | 18 9 | 775 | .569 | .510 | .888 | .685 |
| | | 3,980 | ... | ... | 15 11½ | 20 7½ | 18 3½ | ... | Wake co | | eff. | 1.193 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.02 |
| 35 | *San Francisco* | 4,063 | 310 0 | 49 2 | ... | ... | 18 9 | 770 | .599 | .509 | .873 | .686 |
| | | 4,088 | ... | ... | 17 1 | 20 5 | 18 9 | ... | Wake co | | eff. | 1.016 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.02 |
| 36 | *Cincinnati* | 3,000 | 300 0 | 42 0 | ... | ... | 18 0 | 689 | .605 | .528 | .873 | .669 |
| | | ... | ... | ... | ... | ... | ... | ... | Wake co | | eff. | 1.078 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.08 |
| 37 | *Raleigh* | 3,000 | 300 0 | 42 0 | ... | ... | 18 0 | 689 | .605 | .528 | .873 | .669 |
| | | 3,574 | ... | ... | 17 10 | 19 9 | 18 9½ | ... | Wake co | | eff. | 1.078 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.08 |
| 38 | *Montgomery* | 2,000 | 257 0 | 37 0 | ... | ... | 14 6 | 471 | .605 | .592 | .870 | .700 |
| | | 2,091 | ... | ... | 13 6 | 15 6½ | 14 6½ | ... | Wake co | | eff. | 1.107 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.08 |
| 39 | *Detroit* | 2,000 | 257 0 | 37 0 | ... | ... | 14 6 | 467 9 | .602 | .592 | .870 | .700 |
| | | 2,068 | ... | ... | 13 5 | 15 6½ | 14 5½ | ... | Wake co | | eff. | 1.063 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.08 |
| 40 | *Marblehead* | 2,000 | 257 0 | 37 0 | ... | ... | 14 6 | 464 | .608 | .592 | .870 | .700 |
| | | 2,073 | ... | ... | 13 3½ | 15 5½ | 14 4½ | ... | Wake co | | eff. | 1.057 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.08 |
| 41 | *Columbia* | 7,350 | 411 7 | 58 2 | 23 3 | 23 10 | 22 6 | 1,120 | .566 | .491 | .869 | .652 |
| | (middle propeller) | 7,375 | ... | ... | 21 3 | 23 8 | 22 5½ | ... | Wake co | | eff. | .94 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1 |
| 42 | *Columbia* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | (wing propellers) | ... | ... | ... | ... | ... | ... | ... | Wake co | | eff. | 1.22 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1 08 |
| 43 | *Minneapolis* | 7,350 | 411 7 | 58 2 | 23 3 | 23 9 | 22 6 | 1,125 | .566 | .491 | .869 | .652 |
| | (middle propeller) | 7,387 | ... | ... | 21 8½ | 23 3½ | 22 6 | ... | Wake co | | eff. | 1.099 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1 |
| 44 | *Minneapolis* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | (wing propellers) | ... | ... | ... | ... | ... | ... | ... | Wake co | | eff. | 1.194 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.08 |
| 45 | *Olympia* | 5,500 | 340 0 | 53 0½ | ... | ... | 21 6½ | 970 | .587 | .517 | .886 | .744 |
| | | 5,586 | ... | ... | 19 3½ | 22 2 | 20 8½ | ... | Wake co | | eff. | 1.074 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.074 |

*a*. Trial results.....*b*. Proposed screw.....*c*. Blades set as cast.....*d*. From own performance.....*e*. Pitch axially expanding.....*f*. True screw.....*g*. Pitch as cast, 20 feet 6 inches.....*h*. From *Raleigh's* performance.....*i*. From performance of *Baltimore's*

OF U. S. NAVAL VESSELS.

| Performance. | | | Propellers. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Speed. | Revs. | I.H.P. | Number. | Blades. | D. | P. | P/D | Hel. area. | Proj. area. | Hel. area / Disc. area | App. slip. | Effic. | Ind. thrust per sq. ft. Hel. area. | Ind. thrust per sq. ft. Proj. area. | Remarks. |
| *knots.* | | | | | *ft. ins.* | *ft.* | | | | | | | | | |
| 22 | 120 | 23,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 18 0 | 21.42 | 1.19 | 102.8 | 81.2 | .4 | 13.27 | 68.5 | 1,436 | 1,818 | *b.* |
| 19 | 110 | 9,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 20.8 | 120.5 | 9 248 | .. | .. | 14 6 | 20 | 1.38 | 57.2 | 45 | .346 | 12.6 | 68 15 | 1,102 | 1,400 | *a,f,c.* |
| 20.8 | 120.5 | 9,248 | .. | .. | 14 6 | 20 | 1.38 | 57.2 | 45 | .346 | 12.6 | 68.15 | 1,102 | 1,400 | *d,b,l.* |
| 19 | 110 | 9,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 19.67 | 119.5 | 8,533 | .. | .. | 14 6 | 20.4 | 1.41 | 57.2 | 43.9 | .346 | 18.2 | 67.05 | 1,010 | 1,316 | *a,f,g.* |
| 20 | 120 | 9,000 | .. | .. | 14 6 | 19.58 | 1.35 | 57.2 | 45 | .346 | 13.7 | 68.4 | 1,105 | 1,405 | *i,b,l.* |
| 19 | 120 | 8,500 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 19 | 127 | 8,572 | .. | .. | 14 6 | 18.93 | 1 308 | 52 8 | 40 | .319 | 20.1 | 67.1 | 1,116 | 1,472 | *a,f,c.* |
| 19 | 120 | 8,500 | .. | .. | 14 6 | 18.41 | 1.27 | 57.2 | 44.6 | .346 | 12.9 | 69 | 1,110 | 1,424 | *b.* |
| 19 | 110 | 9,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 19.51 | 124 8 | 9,581 | .. | .. | 13 6 | 18.75 | 1.39 | 57.6 | 44.5 | .402 | 14 45 | 69 | 1,175 | 1,424 | *a,e,c.* |
| 19.51 | 124.8 | 9,581 | .. | .. | 14 6 | 18.27 | 1.26 | 57.2 | 44.6 | .346 | 13.3 | 69 | 1,212 | 1,554 | *b.* |
| 19 | 164 | 7,500 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 19.27 | 140.8 | 6,714 | .. | .. | 13 6 | 15.5 | 1.15 | 50 | 40 | .349 | 10.53 | 67.3 | 1,015 | 1,269 | *a,f,c.* |
| 20.11 | 164 | 7,500 | .. | .. | 12 0 | 14.3 | 1.19 | 45.24 | 35.9 | .4 | 13.1 | 68.4 | 1,166 | 1,470 | *h,n,b.* |
| 19 | 164 | 7,500 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 19.27 | 140.8 | 6,714 | .. | .. | 13 6 | 15.5 | 1.15 | 50 | 40 | .349 | 10.53 | 67.3 | 1,015 | 1,269 | *a,f,c.* |
| 20.11 | 164 | 7,500 | .. | .. | 12 0 | 14.3 | 1.19 | 45.24 | 35.9 | .4 | 13.1 | 68.4 | 1,156 | 1,470 | *b,n.* |
| 18 | 185 | 5,400 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 19 05 | 180.2 | 5,484 | .. | .. | 11 0 | 12.75 | 1.16 | 29 | 23.13 | .305 | 15.49 | 68.6 | 1,250 | 1,568 | *a,f,p.* |
| 19.05 | 180.2 | 5,484 | .. | .. | 11 0 | 12.43 | 1.13 | 32.3 | 26.05 | .34 | 14.2 | 68.6 | 1,245 | 1,544 | *b.* |
| 18 | 185 | 5,400 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 18 71 | 170 | 5,154 | .. | .. | 11 0 | 13 | 1.181 | 29 | 23.1 | .305 | 14.64 | 69 | 1,328 | 1,666 | *a,f,p.* |
| 19.05 | 180.2 | 5,484 | .. | .. | 11 0 | 12.43 | 1 13 | 32.3 | 26.05 | .34 | 14.2 | 68.6 | 1,245 | 1,544 | *b,k.* |
| 18 | 185 | 5,400 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 18.4 | 176 | 4,863 | .. | .. | 11 0 | 12 | 1.09 | 33.3 | 27.5 | .35 | 12.08 | 68.7 | 1,141 | 1,382 | *a,f,o.* |
| 19.05 | 180.2 | 5,484 | .. | .. | 11 0 | 12.43 | 1.13 | 32.3 | 26.05 | .34 | 14.2 | 68.6 | 1,245 | 1,544 | *b,k.* |
| 21 | 129 | 7,000 | 1 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 22.8 | 127.7 | 5,286 | .. | .. | 14 0 | 21.5 | 1.55 | 53.3 | 40.2 | .346 | 15.85 | 66.8 | 1,192 | 1,580 | *a,f,g.* |
| 23.07 | 132.2 | 7,219 | .. | .. | 15 0 | 19.35 | 1.29 | 70.7 | 54.1 | .4 | 12 5 | 68 75 | 1,316 | 1,720 | *b,n.* |
| 21 | 129 | 14,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 22.8 | 133.5 | 12,166 | .. | .. | 15 0 | 21.5 | 1.45 | 53.7 | 41.3 | .304 | 19.47 | 65.8 | 1,304 | 1,695 | *a,f,g.* |
| 23.07 | 132.5 | 13,148 | .. | .. | 14 0 | 20 7 | 1.49 | 61.56 | 44.2 | .4 | 18.4 | 68.4 | 1,285 | 1,789 | *b.* |
| 21 | 129 | 7,000 | 1 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 23.07 | 132.2 | 7,219 | .. | .. | 14 0 | 21.5 | 1.55 | 53.3 | 40.2 | .346 | 17.73 | 69 | 1,572 | 2,085 | *a,f,g.* |
| 23.07 | 132.2 | 7,219 | .. | .. | 15 0 | 19.35 | 1.29 | 70.7 | 54.1 | .4 | 12.5 | 68.75 | 1,316 | 1,720 | *b.* |
| 21 | 129 | 14,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 23.07 | 132.5 | 13,148 | .. | .. | 15 0 | 22 | 1.46 | 53.7 | 41 2 | .304 | 19.8 | 66.2 | 1,386 | 1,806 | *a,f,g.* |
| 23.07 | 132.5 | 13,148 | .. | .. | 14 0 | 20.7 | 1.49 | 61.56 | 44.2 | .4 | 18 4 | 68.4 | 1 285 | 1,789 | *b.* |
| 20 | 129 | 13,500 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 21.68 | 139.2 | 16,850 | .. | .. | 14 9 | 19 | 1.288 | 68 | 52.1 | .397 | 16.8 | 68.3 | 1,516 | 2,018 | *a,e,c.* |
| 21.68 | 139.2 | 16,850 | .. | .. | 14 9 | 19 | 1.288 | 68 | 52.1 | .397 | 16.8 | 68.3 | 1,516 | 2,018 | *b.* |

engines.....*k.* From *Montgomery's* trial.....*l.* Speed by $P : P_3 :: S^3 : S_3{}^3$.....*m.* From speed curve.....*o.* Pitch as cast, 12 feet 6 inches.....*p.* Pitch as cast, 14 feet.....*q.* Pitch as cast, 20 feet.

SCREW PROPELLERS

| Reference No. | Name of vessel. | Displacement. | Dimensions. | | | | | Area immersed midship sect. | Hull coefficients. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Length L.W.L. | Beam. | Draft, for'd. | Draft, aft. | Draft, mean. | | Cyl. | Extr. dim. | Mid. ship sec't. | L.W. plane. |
| | | | *ft. ins.* | *ft. ins.* | *ft. ins.* | *ft. ins.* | *ft. ins.* | *sq. ft.* | | | | |
| 46 | *Denver* | 3,200 | 292 0 | 44 0 | ... | ... | 15 9 | 609 | .630 | .553 | .879 | .729 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.04 |
| 47 | *Cleveland* | 3,200 | 292 0 | 44 0 | ... | ... | 15 9 | 609 | .630 | .553 | .879 | .729 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.04 |
| 48 | *Chattanooga* | 3,200 | 292 0 | 44 0 | ... | ... | 15 9 | 609 | .630 | .553 | .879 | .729 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.04 |
| 49 | *Des Moines* | 3,200 | 292 0 | 44 0 | ... | ... | 15 9 | 609 | .630 | .553 | .879 | .729 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.04 |
| 50 | *Galveston* | 3,200 | 292 0 | 44 0 | ... | ... | 15 9 | 609 | .630 | .553 | .879 | .729 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.04 |
| 51 | *Tacoma* | 3,200 | 292 0 | 44 0 | ... | ... | 15 9 | 609 | .630 | .553 | .879 | .729 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.04 |
| 52 | *St. Louis* | 9,700 | 424 0 | 66 0 | ... | ... | 22 6 | 1,312 | .610 | .539 | .955 | .673 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.06 |
| 53 | *Milwaukee* | 9,700 | 424 0 | 66 0 | ... | ... | 22 6 | 1,312 | .610 | .539 | .955 | .673 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.06 |
| 54 | *Charleston* | 9,700 | 424 0 | 66 0 | ... | ... | 22 6 | 1,312 | .610 | .539 | .955 | .673 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.06 |
| 55 | *Machias* | 1,177 | 204 0 | 32 1½ | ... | ... | 12 0 | 324.6 | .564 | .504 | .854 | .692 |
| | | 1,067.5 | ... | ... | 10 6½ | 13 0 | 11 9½ | ... | Wa | ke co | eff. | 1 084 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.06 |
| 56 | *Castine* | 1,177 | 204 0 | 32 1½ | ... | ... | 12 0 | 324 6 | .564 | .504 | .854 | .692 |
| | | 1,067.5 | ... | ... | 10 6½ | 13 0 | 11 9½ | ... | Wa | ke co | eff. | 1 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.06 |
| 57 | *Nashville* | 1,371 | 220 0 | 38 0 | ... | ... | 11 0 | 370 | .587 | .518 | .882 | .659 |
| | | 1,364 | ... | ... | 9 9½ | 12 1 | 10 11½ | ... | Wa | ke co | eff. | 1 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1 06 |
| 58 | *Helena* | 1,313 | 250 9 | 40 0 | ... | ... | 8 7½ | 327.1 | .573 | .540 | .942 | .726 |
| | | 1,340 | ... | ... | 8 1½ | 9 1½ | 8 7½ | ... | Wa | ke co | eff. | .854 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1 |
| 59 | *Wilmington* | 1,313 | 250 9 | 40 0 | ... | ... | 8 7½ | 329.5 | .573 | .540 | .942 | .726 |
| | | 1,342 | ... | ... | 8 2½ | 9 1 | 8 7½ | ... | Wa | ke co | eff. | .9 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1 |
| 60 | *Annapolis* | 1,000 | 168 0 | 36 0 | ... | ... | 12 0 | 323 | .503 | .482 | .820 | .743 |
| | | 943 | ... | ... | 11 4 | 11 6½ | 11 5½ | ... | Wa | ke co | eff. | .933 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | .975 |

*a*. Trial results.....*b*. Proposed screw.....*c*. Blades set as cast.

OF U. S. NAVAL VESSELS.

| Performance. | | | Propellers. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Speed. | Revs. | I.H.P. | Number. | Blades. | D. | P. | P/D | Hel. area. | Proj. area. | Hel. area / Disc. area | App. slip. | Effic. | Ind. thrust per sq. ft. Hel. area. | Ind. thrust per sq. ft. Proj. area. | Remarks. |
| *knots.* | | | | | *ft. ins.* | *ft.* | | | | | | | | | |
| 17 | 172 | 4,924 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 11 0 | 11 | 1 | 40.39 | 36 | .43 | 12.02 | ... | 1,029 | 1,155 | |
| 17 | 178 | 4,924 | .. | .. | 11 0 | 11 | 1 | 38 | 32 | .4 | 12.02 | 69 | 1,094 | 1,299 | |
| 16.5 | 172 | 4,500 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| .. | ... | ... | .. | .. | 10 6 | 11.33 | 1.08 | 31.4 | 26.2 | .363 | 14.2 | ... | 1,213 | 1,454 | |
| 16.5 | ... | 4,500 | .. | .. | 11 0 | 11 | 1 | 38 | 32 | .4 | 16.1 | 69 | 981 | 1,165 | |
| 16.5 | 172 | 4,500 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 10 6 | 11.25 | 1.07 | 33.7 | 28.7 | .389 | 13.6 | ... | 1,138 | 1,337 | |
| 16.5 | ... | 4,500 | .. | .. | 11 0 | 11 | 1 | 38 | 32 | .4 | 16.1 | 69 | 981 | 1,165 | |
| 16.5 | 172 | 4,500 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 10 6 | 11.45 | 1.09 | 34 | 29 | .392 | 15.1 | ... | 1,169 | 1,300 | |
| 16.5 | 172 | 4,500 | .. | .. | 11 0 | 11 | 1 | 38 | 32 | .4 | 16 1 | 69 | 981 | 1,165 | |
| 16.5 | 172 | 4,500 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 10 6 | 11.25 | 1.07 | 34 | 29 | .392 | 13 6 | ... | 1,128 | 1,323 | |
| 16 5 | 172 | 4,500 | .. | .. | 11 0 | 11 | 1 | 38 | 32 | .4 | 16.1 | 69 | 981 | 1,165 | |
| 16.5 | 172 | 4,500 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 10 0 | 11.5 | 1.15 | 25.8 | 20.9 | .298 | 15.5 | ... | 1,455 | 1,796 | |
| 16.5 | 172 | 4,500 | .. | .. | 11 0 | 11 | 1 | 38 | 32 | .4 | 16.1 | 69 | 981 | 1,165 | |
| 22 | 133 | 21,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 22 | 133 | 21,000 | .. | .. | 17 0 | 19.21 | 1.13 | 90.8 | 73.2 | .4 | 12.8 | 68.75 | 1,494 | 1,853 | |
| 22 | 133 | 21,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 22 | 133 | 21,000 | .. | .. | 17 0 | 19.21 | 1.13 | 90.8 | 73.2 | .4 | 12.8 | 68.75 | 1,494 | 1,853 | |
| 22 | 133 | 21,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 16 3 | 19.75 | 1.215 | 80 | 64.5 | .385 | 15.13 | ... | ... | ... | |
| 22 | 133 | 21,000 | .. | .. | 17 0 | 19.21 | 1 13 | 90.8 | 73.2 | .4 | 12.8 | 68.73 | 1,494 | 1,853 | |
| 13 | 200 | 1,600 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 15.46 | 216.4 | 1,795 | .. | .. | 7 8 | 8.83 | 1.141 | 15.5 | 10.97 | .336 | 12.7 | 69 | 1,020 | 1,438 | *a,f,c.* |
| 15.46 | 216.4 | 1,795 | .. | .. | 7 8 | 8.58 | 1.12 | 18.5 | 15 | .4 | 10.2 | 69 | 865 | 1,067 | *b.* |
| 13 | 200 | 1,600 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 16.03 | 218.8 | 2,128 | .. | .. | 7 8 | 8.74 | 1.137 | 15.5 | 11 | .336 | 15.6 | 68.5 | 1,184 | 1,670 | *a,f,c.* |
| 15 46 | 216.4 | 1.795 | .. | .. | 7 8 | 8.58 | 1 12 | 18.5 | 15 | .4 | 10 2 | 69 | 865 | 1,067 | *b.* |
| 14 | 300 | 1,750 | 2 | 3 | ... | ... | .. | ... | ... | ... | ... | ... | ... | ... | |
| 16.29 | 3.8 4 | 2,408 | .. | .. | 6 8 | 7 | 1.05 | 13.02 | 10.74 | .358 | 23.5 | 67.2 | 1,460 | 1,771 | *a,f,d.* |
| 10.29 | 3.8 4 | 2.488 | .. | .. | 7 3 | 6 31 | 87 | 16.51 | 14.5 | .4 | 14.8 | 69 | 1,278 | 1,457 | *b.* |
| 13 | 283 | 1,600 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 15.5 | 279.9 | 1,953 | .. | .. | 7 0 | 7.02 | 1.015 | 18.7 | 15.59 | .486 | 20.06 | 60 | 877 | 1,053 | *a,f,c.* |
| 15.5 | 279.9 | 1,953 | .. | .. | 7 0 | 6.37 | .95 | 23.1 | 19.9 | .6 | 11.9 | 69 | 783 | 909 | *b.* |
| 13 | 283 | 1,600 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 15 08 | 273 | 1,862 | .. | .. | 7 0 | 7.04 | 1.018 | 18.7 | 15 59 | .486 | 21.01 | 59 | 855 | 1,025 | *a,f,c.* |
| 15.5 | 279 9 | 1,953 | .. | .. | 7 0 | 6.37 | .95 | 23.1 | 19.9 | .6 | 11 9 | 69 | 783 | 909 | *b.* |
| 12 | 160 | 800 | 1 | 4 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 13.17 | 146.7 | 1,208 | .. | .. | 9 6 | 11 | 1.158 | 30 | 23.95 | .423 | 17.3 | 66.4 | 823 | 1,032 | *a,f,g.* |
| 13.17 | 146.7 | 1,208 | .. | .. | 10 0 | 10.45 | 1.045 | 47.5 | 39.2 | .6 | 12.4 | .69 | 548 | 663 | *b.* |

*d.* Blades set 2 inches above cast pitch.....*f.* True screw.....*g.* Solid blades.

SCREW PROPELLERS

| Reference No. | Name of vessel. | Displacement. | Dimensions. | | | | | Area immersed midship sect. | Hull coefficients. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Length L.W.L. | Beam. | Draft, for'd. | Draft, aft. | Draft, mean. | | Cyl. | Extr. dim. | Mid-ship sec't. | L.W. plane. |
| | | | *ft. ins.* | *ft. ins.* | *ft. ins.* | *ft. ins.* | *ft. ins* | *sq. ft.* | | | | |
| 61 | *Vicksburg* | 1,000 | 168 0 | 36 0 | ... | ... | 12 0 | 342 | .503 | .482 | .820 | .743 |
| | | 964 | ... | ... | 11 2½ | 12 0½ | 11 7⅞ | ... | Wa | ke co | eff. | .964 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | .975 |
| 62 | *Newport* | 1,000 | 168 0 | 36 0 | ... | ... | 12 0 | 344 | .503 | .482 | .820 | .743 |
| | | 972 | ... | ... | 11 1½ | 12 3½ | 11 8¼ | ... | Wa | ke co | eff. | .964 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | .975 |
| 63 | *Princeton* | 1,000 | 168 0 | 36 0 | ... | ... | 12 0 | 372 | .503 | .482 | .820 | .743 |
| | | ... | ... | ... | 12 11 | 12 2 | 12 6¼ | ... | Wa | ke co | eff. | ... |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | .975 |
| 64 | *Wheeling* | 1,000 | 174 0 | 34 0 | ... | ... | 12 0 | 352 | .592 | .508 | .858 | .724 |
| | | 1,000 | ... | ... | 11 9½ | 12 3½ | 12 0⅝ | ... | Wa | ke co | eff. | 1.175 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.10 |
| 65 | *Marietta* | 1,000 | 174 0 | 34 0 | ... | ... | 12 0 | 349 | .592 | .508 | .858 | .724 |
| | | 991 | ... | ... | 11 8½ | 12 2½ | 11 11¼ | ... | Wa | ke co | eff. | 1.178 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.10 |
| 66 | *Bancroft* | 839 | 187 6 | 32 0 | ... | ... | 11 6 | 277 | .561 | .425 | .758 | .667 |
| | | 832 | ... | ... | 10 11 | 11 11½ | 11 5¼ | ... | Wa | ke co | eff. | 1.094 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.06 |
| 67 | *Paducah* | 1,065 | 174 0 | 35 0 | ... | ... | 12 3 | 352 | .610 | .520 | .860 | .710 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.06 |
| 68 | *Dubuque* | 1,065 | 174 0 | 35 0 | ... | ... | 12 3 | 352 | .610 | .520 | .860 | .710 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1 06 |
| 69 | *Monterey* | 4,027 | 256 0 | 59 1½ | ... | ... | 14 6 | 772 | .708 | .643 | .710 | .745 |
| | | 4,000 | ... | ... | 14 5½ | 14 4½ | 14 5 | ... | Wa | ke co | eff. | 1.298 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.04 |
| 70 | *Arkansas* | 3,235 | 252 0 | 50 0 | ... | ... | 12 6 | 597 | .836 | .719 | .955 | .843 |
| | | 3,193 | ... | ... | 12 4$^{9}/_{16}$ | 12 8$^{1}/_{16}$ | 12 6$^{5}/_{32}$ | ... | Wa | ke co | eff. | 1.089 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.04 |
| 71 | *Florida* | 3,235 | 252 0 | 50 0 | ... | ... | 12 6 | 597 | .836 | .719 | .955 | .843 |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.09 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.04 |
| 72 | *Nevada* | 3,235 | 252 0 | 50 0 | ... | ... | 12 6 | 597 | .836 | .719 | .955 | .843 |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.053 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.04 |
| 73 | *Wyoming* | 3,235 | 252 0 | 50 0 | ... | ... | 12 6 | 597 | .836 | .719 | .955 | .843 |
| | | ... | ... | ... | 12 2 | 13 0 | 12 7 | ... | Wa | ke co | eff. | 1.143 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.04 |
| 74 | *Katahdin* | 2,183 | 250 2 | 41 8 | ... | ... | 15 0 | 478.2 | .617 | .461 | .734 | .739 |
| | | 2,125 | ... | ... | 14 4 | 15 4½ | 14 10¼ | ... | Wa | ke co | eff. | 1.048 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.05 |
| 75 | *Perry* | 420 | 244 0 | 23 6 | ... | ... | 6 6 | 126.7 | .655 | .410 | .770 | .720 |
| | | 475.6 | ... | ... | 5 5½ | 8 3$^{11}/_{16}$ | 6 8$^{3}/_{32}$ | ... | Wa | ke co | eff. | 1.215 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.16 |

*a*. Trial results.....*b*. Proposed screw.....*c*. Blades set as cast.....*d*. Solid blades.
*e*. Axially and radially expanding.....*f*. True screw.....*g*. Blades set 1½ inches over cast pitch.....*h*. Blades set 3 inches above cast pitch.....*i*. Mean pitch 12 feet 3 inches.

OF U. S. NAVAL VESSELS.

| Performance. | | | Propellers. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Speed. | Revs. | I.H.P. | Number. | Blades. | D. | P. | $\frac{P}{D}$ | Hel. area. | Proj. area. | Hel. area / Disc. area | App. slip. | Effic. | Ind. thrust per sq. ft. Hel. area. | Ind. thrust per sq. ft. Proj. area. | Remarks. |
| *knots.* | | | | | *ft. ins.* | *ft.* | | | | | | | | | |
| 12 | 150 | 800 | 1 | 4 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 12.67 | 146.5 | 1,084 | .. | .. | 10 0 | 10.63 | 1.063 | 23.3 | 19.15 | .296 | 17.39 | 67.1 | 986 | 1,200 | *a,f,d.* |
| 13.17 | 146.7 | 1,208 | .. | .. | 10 0 | 10.45 | 1.045 | 47.5 | 39.2 | .6 | 12.4 | 69 | 548 | 663 | *b.* |
| 12 | 150 | 800 | 1 | 4 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 12 33 | 142.6 | 976 | .. | .. | 10 0 | 10.45 | 1.045 | 23.3 | 19 26 | .296 | 16.49 | 67.5 | 928 | 1,122 | *a,f,d.* |
| 13.17 | 146.7 | 1,208 | .. | .. | 10 0 | 10.45 | 1.045 | 47.5 | 39.2 | .6 | 12.4 | 69 | 548 | 663 | *b.* |
| 12 | 150 | 800 | 1 | 4 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 11 | 122.7 | 923 | .. | .. | 10 0 | 10.104 | 1.0104 | 31 | 25.9 | .395 | 10.01 | *m.* | 792 | 949 | *a,f,g.* |
| 13.17 | 146.7 | 1,208 | .. | .. | 10 0 | 10.45 | 1.045 | 47.5 | 39.2 | .6 | 12.4 | 69 | 548 | 663 | *b.* |
| 12 | 200 | 800 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 12.88 | 231 | 1,050 | .. | .. | 6 9 | 7.25 | 1.074 | 17 | 13.93 | .475 | 22.2 | 67.9 | 603 | 743 | *a,f,c.* |
| 13.02 | 231.8 | 1,024 | .. | .. | 6 9 | 6.89 | 1.02 | 16.76 | 13.9 | .46 | 17.4 | 69 | 632 | 761 | *b.* |
| 12 | 200 | 800 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 13.02 | 231.8 | 1,024 | .. | .. | 6 9 | 7.25 | 1.074 | 17 | 13.93 | .475 | 21 5 | 68.75 | 591 | 722 | *a,f,c.* |
| 13.02 | 231.8 | 1,024 | .. | .. | 6 9 | 6.89 | 1.02 | 16.76 | 13.9 | .46 | 17.4 | 69 | 632 | 761 | *b.* |
| 12 | 240 | 1,300 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 14.37 | 222.4 | 1,184 | .. | .. | 7 0 | 7.75 | 1.107 | 15 | 10.66 | .389 | 15.5 | 68.9 | 756 | 1,063 | *a,f,h.* |
| 14.60 | 240 | 1,300 | .. | .. | 7 0 | 7.14 | 1.02 | 14.63 | 12.2 | .380 | 13.6 | 69 | 855 | 1,026 | *b.* |
| 13 | 225 | 1,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 7 3 | 6.82 | .94 | 13.62 | 11.6 | .330 | 14.15 | 69 | 789 | 927 | |
| 13 | 225 | 1,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 7 3 | 6.82 | .94 | 13.62 | 11.6 | .330 | 14.15 | 69 | 789 | 927 | |
| 16 | 150 | 5,400 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 13.6 | 161.5 | 4,987 | .. | .. | 10 2 | 11.67 | 1.148 | 39 | 29.07 | .48 | 26.8 | 62 | 1,140 | 1,528 | *a,e,i.* |
| 13 6 | 161.5 | 4,987 | .. | .. | 11 0 | 11.11 | 1·01 | 45.6 | 38 | .48 | 23.2 | 67.1 | 1,006 | 1,207 | *b.* |
| 11 5 | 200 | 2,400 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 12.71 | 214.5 | 2,190 | .. | .. | 9 0 | 7.25 | .805 | 25.6 | 22.35 | .402 | 17.18 | 69 | 908 | 1,040 | *a,f,c.* |
| 13.98 | 200 | 2,400 | .. | .. | 9 0 | 8.28 | .92 | 28 | 24.1 | .44 | 14.46 | 69 | 854 | 992 | *b.* |
| 11.5 | 200 | 2,400 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | 885 | 1,046 | |
| 12.4 | 199.61 | 2,317 | .. | .. | 8 6 | 8.32 | .98 | 26 | 22 | .458 | 24.45 | 67.9 | ... | ... | *a,f,c.* |
| 13.98 | 200 | 2,400 | .. | .. | 9 0 | 8.28 | .92 | 28 | 24.1 | .44 | 14 46 | 69 | 854 | 992 | *b.* |
| 11.5 | 200 | 2,400 | 2 | 3 | ... | ... | .. | ... | ... | ... | ... | ... | ... | ... | |
| 13.04 | 187 | 1,940 | .. | .. | 9 2½ | 7.8 | .848 | 24 | 21.13 | .359 | 9.57 | 69 | 956 | 1,039 | *a,f,k.* |
| 13.98 | 200 | 2,400 | .. | .. | 9 0 | 8 28 | .92 | 28 | 24.1 | .44 | 14.46 | 69 | 854 | 992 | *b.* |
| 11.5 | 200 | 2,400 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 12.37 | 214.7 | 2,811 | .. | .. | 8 0 | 8.5 | 1.063 | 25.8 | 21.78 | .513 | 31.3 | 66.6 | 985 | 1,167 | *a,f,c.* |
| 13 98 | 200 | 2,400 | 2 | 3 | 9 0 | 8.28 | .92 | 28 | 24.1 | .44 | 14 46 | 69 | 854 | 992 | *b.* |
| 17 | 150 | 4,800 | 2 | 3 | 10 10½ | 14.33 | 1.41 | 38.56 | 28.4 | .419 | ... | 68.5 | ... | ... | *f,c,l.* |
| 10.09 | 139.54 | 4,904 | .. | .. | 12 0 | 14 | 1.167 | 36.25 | 28.65 | .318 | 19.9 | 69 | 1,143 | 1,446 | *f,c,m.* |
| 10.09 | 139 54 | 4,904 | .. | .. | 12 0 | 13.68 | 1.140 | 54.25 | 43.8 | .480 | 14.6 | 69 | 781 | 968 | *b.* |
| 29 | 327 | 8,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 28.48 | 372 | 9,240 | .. | .. | 7 5 | 10.83 | 1.46 | 16.83 | 11.9 | .39 | 28.5 | 66 | 2,248 | 3,180 | *a,f.* |
| 30 | 335 | 8,400 | .. | .. | 7 6 | 10.95 | 1.46 | 22.1 | 16 | .5 | 16.9 | 66.5 | 1,709 | 2,362 | *b.* |

*k.* Blades set 9.6 inches above cast pitch.....*l.* Abandoned.....*m.* Used for final trial.
*n.* Off chart.

SCREW PROPELLERS

| Reference No. | Name of vessel. | Displacement. | Dimensions. | | | | | Area immersed midship sect. | Hull coefficients. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Length L.W.L. | Beam. | Draft, for'd. | Draft, aft. | Draft, mean. | | Cyl. | Extr. dim. | Mid-ship sec't. | L.W. plane. |
| | | | *ft. ins.* | *ft. ins.* | *ft. ins.* | *ft. ins.* | *ft. ins.* | *sq. ft.* | | | | |
| 76 | *Jaul Jones* | 420 | 244 0 | 23 6½ | ... | ... | 6 6 | 146.7 | .655 | .410 | .77 | .72 |
| | | 470 | ... | ... | 5 5½ | 8 3 1/16 | 6 8 1/16 | ... | Wa | ke co | eff. | 1.17 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.16 |
| 77 | *Preble* | 420 | 244 0 | 23 6¼ | ... | ... | 6 6 | 127.6 | .661 | .410 | .77 | .72 |
| | | 480 | ... | ... | 5 11½ | 8 4½ | 7 1 5/16 | ... | Wa | ke co | eff. | 1.17 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.16 |
| 78 | *Bainbridge* | 420 | 240 6 | 23 0½ | ... | ... | 6 6 | 112.5 | .568 | .430 | .703 | .712 |
| | | 460 | ... | ... | 5 6 | 8 8½ | 7 1½ | ... | Wa | ke co | eff. | 1.183 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.16 |
| 79 | *Barry* | 420 | 240 6 | 23 0½ | ... | ... | 6 6 | 112.5 | .568 | .430 | .703 | .712 |
| | | 461.6 | ... | ... | 5 6 | 8 8½ | 7 1½ | ... | Wa | ke co | eff. | 1.216 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.16 |
| 80 | *Chauncey* | 420 | 240 6 | 23 0½ | ... | ... | 6 6 | 112.5 | .568 | .430 | .703 | .712 |
| | | 463 | ... | ... | 5 6 | 8 8½ | 7 1½ | ... | Wa | ke co | eff. | 1.227 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.16 |
| 81 | *Stewart* | 420 | 245 0 | 23 7½ | ... | ... | 6 6 | 112.5 | .564 | .410 | .692 | .698 |
| | | 435 | ... | ... | 5 5½ | 8 7½ | 7 0½ | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.16 |
| 82 | *Dale* | 420 | 245 0 | 23 1½ | ... | ... | 6 6 | 108.8 | .600 | .461 | .658 | .701 |
| | | 457 | ... | ... | 5 6½ | 8 10½ | 7 1½ | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.16 |
| 83 | *Decatur* | 420 | 245 0 | 23 1½ | ... | ... | 6 6 | 107.52 | .598 | .467 | .668 | .701 |
| | | 450 | ... | ... | 5 3½ | 8 9½ | 6 11½ | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.16 |
| 84 | *Truxtun* | 433 | 258 6 | 23 3 | ... | ... | 6 0 | 139 | .648 | .370 | .675 | .726 |
| | | 479 | ... | ... | 6 2 | 9 7½ | 7 10½ | ... | Wa | ke co | eff. | 1.165 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.16 |
| 85 | *Whipple* | 433 | 258 6 | 23 3 | ... | ... | 6 0 | 139 | .648 | .370 | .675 | .726 |
| | | 480.2 | ... | ... | 6 0 | 9 8 | 7 10 | ... | Wa | ke co | eff. | 1.20 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.16 |
| 86 | *Worden* | 433 | 258 6 | 23 3 | ... | ... | 6 0 | 139 | .648 | .370 | .675 | .726 |
| | | 482.3 | ... | ... | 6 1½ | 9 7½ | 7 10 7/16 | ... | Wa | ke co | eff. | 1.175 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.16 |
| 87 | *Hopkins* | 408 | 244 0 | 24 6 | ... | ... | 6 6½ | 97.8 | .597 | .400 | .655 | .666 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1 12 |
| 88 | *Hull* | 408 | 244 0 | 24 6 | ... | ... | 6 6½ | 97.8 | .597 | .400 | .655 | .666 |
| | | 432.5 | ... | ... | 4 2½ | 9 6½ | 7 2½ | ... | Wa | ke co | eff. | 1.19 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.12 |
| 89 | *Lawrence* | 402 | 240 10 | 22 3 | ... | ... | 6 6 | 110.5 | .528 | .404 | .755 | .671 |
| | | 412.1 | ... | ... | 5 2½ | 7 10½ | 6 6½ | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 90 | *Macdonough* | 402 | 240 10 | 22 3 | ... | ... | 6 6 | 110.5 | .528 | .404 | .755 | .671 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |

*a.* Trial results .....*b.* Proposed screw.
*c.* Pitch expanding radially and axially.....*f.* True screw.

OF U. S. NAVAL VESSELS.

| Performance. | | | Propellers. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Speed. | Revs. | I.H.P. | Number. | Blades. | D. | P. | $\frac{P}{D}$ | Hel. area. | Proj. area. | Hel. area / Disc. area | App. slip. | Effic. | Ind. thrust per sq. ft. Hel. area. | Ind. thrust per sq. ft. Proj. area. | Remarks. |
| *knots.* | | | | | *ft. ins.* | *ft.* | | | | | | | | | |
| 29 | 327 | 8,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 28.91 | 330.5 | 7,500 | " | " | 7 5 | 10.66 | 1.44 | 24 | 18.6 | .556 | 18.3 | 65.8 | 1,437 | 1,855 | *a,f.* |
| 30 | 335 | 8,400 | " | " | 7 6 | 10.95 | 1.46 | 22.1 | 16 | .5 | 16.9 | 66.5 | 1,709 | 2,362 | *b.* |
| 29 | 327 | 8,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 28.13 | 337 | 7,200 | " | " | 7 5 | 10.4 | 1.4 | 20.33 | 15.46 | .470 | 19.33 | 66.5 | 1,584 | 2,083 | *a,f.* |
| 30 | 335 | 8,400 | " | " | 7 6 | 10.95 | 1.46 | 22.1 | 16 | .5 | 16.9 | 66.5 | 1,709 | 2,362 | *b.* |
| 29 | 327 | 8,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 28.45 | 334.6 | 8,450 | " | " | 8 0 | 10.61 | 1.326 | 24.9 | 20 | .510 | 18.59 | 65 | 1,577 | 1,964 | *a,f.* |
| 30 | 335 | 8,400 | " | " | 7 6 | 10.95 | 1.46 | 22.1 | 16 | .5 | 16.9 | 66.5 | 1,709 | 2,362 | *b.* |
| 29 | 327 | 8,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 28.13 | 324 | 7,950 | " | " | 8 0 | 11.255 | 1.4 | 24.9 | 20 | .510 | 22.43 | 64.2 | 1,455 | 1,798 | *a,f.* |
| 30 | 335 | 8,400 | " | " | 7 6 | 10.95 | 1.46 | 22.1 | 16 | .5 | 16.9 | 66.5 | 1,709 | 2,362 | *b.* |
| 29 | 327 | 8,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 28.64 | 327.6 | 8,130 | " | " | 8 0 | 11.073 | 1.384 | 24.9 | 20 | .510 | 20 57 | 64.5 | 1,485 | 1,849 | *a,f.* |
| 30 | 335 | 8,400 | " | " | 7 6 | 10.95 | 1.46 | 22.1 | 16 | .5 | 16.9 | 66.5 | 1,709 | 2,362 | *b.* |
| 29 | 327 | 8,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 29.69 | 335 | ... | " | " | 8 0 | 10.7 | 1.34 | 23.32 | 17.68 | .462 | 16.1 | ... | ... | ... | *a,f.* |
| 30 | 335 | 8,400 | " | " | 7 6 | 10.95 | 1.46 | 22.1 | 16 | .5 | 16.9 | 66.5 | 1,709 | 2,362 | *b.* |
| 28 | 330 | 8,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 28.005 | 331.75 | ... | " | " | 7 10 | 10.25 | 1.308 | 21 | 16 | .436 | 13.8 | ... | ... | ... | *a,f.* |
| 30 | 335 | 8,400 | " | " | 7 6 | 10.95 | 1.46 | 22.1 | 16 | .5 | 16.9 | 66.5 | 1,709 | 2,362 | *b.* |
| 28 | 330 | 8,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 28.23 | 331.45 | ... | " | " | 7 10 | 10.25 | 1.308 | 21 | 16 | .436 | 16.38 | ... | ... | ... | *a,f.* |
| 30 | 335 | 8,400 | " | " | 7 6 | 10.95 | 1.46 | 22.1 | 16 | .5 | 16.9 | 66.5 | 1,709 | 2,362 | *b.* |
| 30 | 327 | 8,300 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 29.58 | 328.65 | 7,846 | " | " | 8 0 | 11.25 | 1.406 | 22.7 | 17.14 | .452 | 18.93 | ... | 1,542 | 2,043 | *a,f.* |
| 30 | 327 | 8,300 | " | " | 7 6 | 11.15 | 1 5 | 22.1 | 15.8 | .5 | 16.5 | 66.6 | 1,700 | 2,377 | *b.* |
| 30 | 327 | 8,300 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 28.24 | 316.7 | 7,202 | " | " | 8 0 | 11.25 | 1.406 | 22.7 | 17.14 | .452 | 19.72 | ... | 1,469 | 1,946 | *a,f.* |
| 30 | 327 | 8,300 | " | " | 7 6 | 11.15 | 1.5 | 22.1 | 15.8 | .5 | 16.5 | 66.6 | 1,700 | 2,377 | *b.* |
| 30 | 327 | 8,300 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 29.78 | 319.6 | 7,987 | " | " | 8 0 | 11.25 | 1.406 | 22.7 | 17.14 | .452 | 18.84 | 64.9 | 1,615 | 2,138 | *a,f.* |
| 30 | 327 | 8,300 | " | " | 7 6 | 11.15 | 1.5 | 22.1 | 15.8 | .5 | 16 5 | 66.6 | 1,700 | 2,377 | *b.* |
| 29 | 400 | 7,200 | 2 | 3 | ... | ... | .. | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | " | " | 7 8 | 8.27 | 1.078 | 21.75 | 17.5 | .471 | ... | 65.9 | ... | ... | *a,e,** |
| 29 | 415.5 | 8,978 | " | " | 8 0 | 8 | 1 | 27.15 | 22.8 | .54 | 11.6 | 65.5 | 1,642 | 1,954 | *b.* |
| 29 | 400 | 7,200 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 28.2 | 415.5 | 8,978 | " | " | 7 8 | 8.27 | 1.078 | 21.75 | 17.5 | .471 | 14.3 | 65.9 | 2,160 | 2,470 | *a,e.* |
| 29 | 415.5 | 8,978 | " | " | 8 0 | 8 | 1 | 27.15 | 22.8 | .54 | 11.6 | 65.5 | 1,642 | 1,954 | *b.* |
| 30 | 370 | 8,400 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 28.41 | 352.9 | ... | " | " | 7 4½ | 9.508 | 1.3 | 21.77 | 17.14 | .515 | ... | ... | ... | ... | *a,f.* |
| ... | ... | ... | " | " | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 30 | 370 | 8,400 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 28 | 360.46 | ... | " | " | 7 4½ | 9.508 | 1.3 | 21.77 | 17.14 | .515 | 17.10 | ... | ... | ... | *a,f.* |
| ... | ... | ... | " | " | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |

*Changed to 8 feet diameter, 8 feet 6 inches pitch; $\frac{P}{D}$ = 1.06; helicoidal area, 24 square feet. With this propeller a speed of over 29 knots has been made with 398 revolutions.

SCREW PROPELLERS

| Reference No. | Name of vessel. | Displacement. | Dimensions. | | | | | Area immersed midship sect. | Hull coefficients. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Length L.W.L. | Beam. | Draft, for'd. | Draft, aft. | Draft, mean. | | Cyl. | Extr. dim. | Mid-ship sec't. | L.W. plane. |
| | | | *ft. ins.* | *ft. ins.* | *ft. ins.* | *ft. ins.* | *ft. ins.* | *sq. ft.* | | | | |
| 91 | *Ericsson* | 120 | 149 7 | 15 6 | ... | ... | 4 10½ | 51.5 | .572 | .391 | .7 | .64 |
| | | 126 | ... | ... | 4 10½ | 4 10 | 4 10⅜ | ... | Wake coeff. | | | .853 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.08 |
| 92 | *Cushing* | 105 | 137 6 | 14 3 | ... | ... | 4 10½ | 48 | .558 | .386 | .7 | .64 |
| | | 105.3 | ... | ... | ... | ... | ... | ... | Wake coeff. | | | 1.075 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.075 |
| 93 | *Foote* | 142 | 160 0 | 16 0½ | ... | ... | 5 0 | 58.5 | .517 | .377 | .72 | .61 |
| | | 138.3 | ... | ... | ... | ... | 5 0 | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wake coeff. | | | 1.16 |
| 94 | *Rodgers* | 142 | 160 0 | 16 0½ | ... | ... | 5 0 | 64.5 | .499 | .364 | .72 | .61 |
| | | 147 | ... | ... | ... | ... | 5 5 | ... | Wake coeff. | | | 1.215 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.16 |
| 95 | *Winslow* | 142 | 160 0 | 16 0½ | ... | ... | 5 0 | 58.5 | .517 | .37 | .72 | .61 |
| | | 138 | ... | ... | 4 0 | 6 7 | 5 3½ | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wake coeff. | | | 1.16 |
| 96 | *Porter* | 165 | 175 0 | 17 8½ | ... | ... | 4 8½ | 60 | .516 | .399 | .72 | .68 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 97 | *Dupont* | 165 | 175 0 | 17 8½ | ... | ... | 4 8½ | 60 | .516 | .399 | .72 | .68 |
| | | ... | ... | ... | ... | ... | 4 9⅛ | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 98 | *Rowan* | 182 | 170 0 | 17 0 | ... | ... | 5 6 | 78 | .486 | .372 | .75 | .67 |
| | | 184.25 | ... | ... | ... | ... | 5 11⅛ | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 99 | *Dahlgren* | 146.5 | 147 0 | 16 4½ | ... | ... | 4 7½ | 60 | .659 | .447 | .724 | .743 |
| | | 132 | ... | ... | ... | ... | 4 3⅛ | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wake coeff. | | | 1.16 |
| 100 | *Craven* | 146.5 | 147 0 | 16 4½ | ... | ... | 4 7½ | 60 | .659 | .448 | .724 | .743 |
| | | 132.7 | ... | ... | ... | ... | 4 3⅛ | ... | Wake coeff. | | | 1.225 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.16 |
| 101 | *Farragut* | 279 | 213 6 | 20 7½ | ... | ... | 6 0 | 82 | .472 | .369 | .614 | .68 |
| | | 236.3 | ... | ... | 4 9½ | 8 2½ | 6 5⅛ | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 102 | *Davis* | 154 | 146 0 | 15 4 | ... | ... | 5 10 | 63 | .586 | .371 | .74 | ... |
| | | 126 | ... | ... | 4 5½ | 6 1½ | 5 3⅛ | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 103 | *Fox* | 154 | 146 0 | 15 4 | ... | ... | 5 10 | 63 | .586 | .372 | .74 | ... |
| | | 123 | ... | ... | ... | ... | 5 2 | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 104 | *Talbot* | 46.5 | 99 6 | 12 6 | ... | ... | 3 10 | 29 | .564 | .337 | .8 | .76 |
| | | 45.75 | ... | ... | ... | ... | 3 9⅛ | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 105 | *Gwin* | 46.5 | 99 6 | 12 6 | ... | ... | 3 10 | 29 | .564 | .334 | .8 | .76 |
| | | 44.5 | ... | ... | ... | ... | 3 9⅛ | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |

OF U. S. NAVAL VESSELS.

| Performance. | | | Propellers. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Speed. | Revs. | I.H.P. | Number. | Blades. | D. | P. | P/D | Hel. area. | Proj. area. | Hel. area / Disc. area | App. slip. | Effic. | Ind. thrust per sq. ft. Hel. area. | Ind. thrust per sq. ft. Proj. area. | Remarks. |
| *knots.* | | | | | *ft. ins.* | *ft.* | | | | | | | | | |
| 24 | 412 | 1,800 | 2 | 4 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 21.24 | 375.1 | 1,742 | .. | .. | 4 10 | 6.33 | 1.31 | 10 82 | 8 26 | .589 | 9.4 | 67 6 | 1,110 | 1,465 | *a, f.* |
| 21.24 | 375.1 | 1,742 | .. | .. | 4 10 | 6.96 | 1.44 | 11 | 8 | .6 | 17 5 | 69 | 1,001 | 1,370 | *b.* |
| 22 | 370 | 1,600 | 2 | 4 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 22 5 | 370 | 1,755 | .. | .. | 4 3 | 8.41 | 1.98 | 9.3 | 5.7 | .656 | 26.8 | 68.3 | 1,001 | 1,034 | *a, f.* |
| 22.5 | 370 | 1,755 | .. | .. | 4 3 | 8.41 | 1.98 | 9 3 | 5.7 | .656 | 26.8 | 68 3 | 1,001 | 1,634 | *b.* |
| 24.5 | 412 | 2,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 24.53 | 395.7 | ... | .. | .. | 5 3 | 7 83 | 1.51 | 9 63 | 7.93 | .447 | 19.5 | 66.5 | ... | ... | *a, f.* |
| 24.25 | 412 | 2,306 | .. | .. | 5 0 | 7.46 | 1.50 | 9.5 | 7.15 | .4 | 20.3 | 60.5 | 1,265 | 1,542 | *b.* |
| 24.5 | 412 | 2,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 24 25 | 395 8 | 2,306 | .. | .. | 5 3 | 7.82 | 1 49 | 9.68 | 7.93 | .447 | 20.94 | 66 5 | 1,270 | 1,546 | *a, f.* |
| 24.25 | 412 | 2,306 | .. | .. | 5 0 | 7 48 | 1.30 | 9.5 | 7.15 | .4 | 20 3 | 60.5 | 1,265 | 1,542 | *b.* |
| 24.5 | 412 | 2,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 24 82 | 393.92 | ... | .. | .. | 5 3 | 7.80 | 1 49 | 9.68 | 7.93 | .447 | 18.16 | 66 5 | ... | ... | *a, f.* |
| 24.25 | 412 | 2,306 | .. | .. | 5 0 | 7..8 | 1 30 | 9 5 | 7 15 | .4 | 20.3 | 60.5 | 1,265 | 1,542 | *b.* |
| 27 5 | 395 | 3,200 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 28.6 | 389.5 | ... | .. | .. | 5 4 | 8.71 | 1.63 | 10.69 | 7.27 | .478 | 14.3 | ... | ... | ... | *a, f.* |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 27.5 | 395 | 3,200 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 5 4 | 8.71 | 1.63 | 10.69 | 7.27 | .478 | ... | ... | ... | ... | *a, f.* |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 26 | 395 | 3,200 | 2 | 4 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 27.07 | 368 | ... | .. | .. | 6 0 | 9 | 1.5 | 12.7 | 9 | .449 | 17.2 | ... | ... | ... | *a, f.* |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 30.5 | 340 | 4,200 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 30.01 | 314.4 | ... | .. | .. | 6 5 | 11.44 | 1.79 | 13.65 | 8.71 | .422 | 16 4 | 60 | ... | ... | *a, f.* |
| 30.74 | 329 | 3,662 | .. | .. | 6 5 | 11.15 | 1 74 | 13.20 | 8.8 | .41 | 17.8 | 63.1 | 1,242 | 1,872 | *b.* |
| 30.5 | 340 | 4,200 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 30.74 | 329 | 3,662 | .. | .. | 6 5 | 11.54 | 1.8 | 13.38 | 8.85 | .413 | 18 | 60 | 1,166 | 1,800 | *a, f.* |
| 30.74 | 329 | 3,662 | .. | .. | 6 5 | 11.15 | 1.74 | 13.26 | 8.8 | .41 | 17.8 | 63.1 | 1,242 | 1,872 | *b.* |
| 30 | 400 | 5,600 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 30.62 | 427.6 | ... | .. | .. | 6 9 | 8.75 | 1.29 | 12 | 9 | .335 | 17.25 | ... | ... | ... | *a, f.* |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 22.5 | 395 | 1,750 | 2 | 3 | ... | ... | .. | ... | ... | ... | ... | ... | ... | ... | |
| 23.4 | 382 | ... | .. | .. | 4 10½ | 7.25 | 1.48 | 8.5 | 6.4 | .456 | 14 48 | ... | ... | ... | *a, f.* |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 22.5 | 395 | 1,750 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 23.13 | 380.4 | ... | .. | .. | 4 10½ | 7.25 | 1.48 | 8 5 | 6.4 | .456 | 15.02 | ... | ... | ... | *a, f.* |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 20 | 400 | 850 | 1 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 21.15 | 437 9 | ... | .. | .. | 4 8 | 6.05 | 1.29 | 6.9 | 5 3 | .403 | 19 4 | ... | ... | ... | *a, f.* |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 20 | 400 | 850 | 1 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 20.88 | 442.3 | ... | .. | .. | 4 8 | 6.26 | 1.33 | 6.9 | 5.28 | .403 | 23.8 | ... | ... | ... | *a, f.* |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |

*a.* Trial results.....*b.* Proposed screw.....*f.* True screw.

SCREW PROPELLERS

| Reference No. | Name of vessel. | Displacement. | Dimensions. | | | | | Area immersed midship sect. | Hull coefficients. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Length L.W.L. | Beam. | Draft, for'd. | Draft, aft. | Draft, mean. | | Cyl. | Extr. dim. | Midship sec't. | L.W. plane. |
| | | | *ft. ins.* | *ft. ins.* | *ft. ins.* | *ft. ins.* | *ft. ins.* | *sq. ft.* | | | | |
| 106 | *Morris*..... | 114.75 | 138 3 | 15 6 | ... | ... | 4 3 | 52.2 | .475 | .38 | .8 | ... |
| | | 98 | ... | ... | ... | ... | 4 2½ | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 107 | *Mackenzie*..... | 65 | 99 3 | 12 9½ | ... | ... | 4 3 | 38 | .603 | .42 | .7 | .67 |
| | | 76 | ... | ... | 4 4 | 5 1 | 4 6½ | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 108 | *McKee*..... | 65 | 99 3 | 12 9½ | ... | ... | 4 3 | 36.5 | .629 | .42 | .673 | .698 |
| | | 76 | ... | ... | ... | ... | 4 8½ | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 109 | *Stringham*..... | 340 | 225 0 | 22 0 | ... | ... | 6 6 | 103.5 | .511 | .418 | .724 | .68 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 110 | *Goldsborough*... | 247.5 | 194 8 | 20 5 | ... | ... | 5 0 | 78.4 | .591 | .448 | .769 | ... |
| | | 255 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 111 | *Bailey*..... | 235 | 205 0 | 18 9½ | ... | ... | 6 0 | 72.77 | .643 | .374 | .574 | .79 |
| | | 280.9 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 112 | *Bagley* ..... | 167 | 157 0 | 16 2½ | ... | ... | 4 7½ | 56.8 | .659 | .478 | .724 | .743 |
| | | 168 | ... | ... | 4 8½ | 4 11½ | 4 10 | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.16 |
| 113 | *Barney*..... | 167 | 157 0 | 16 2½ | ... | ... | 4 7½ | 56.8 | .659 | .478 | .724 | .743 |
| | | 168 | ... | ... | 4 8½ | 4 11½ | 4 10 | ... | ... | Wake co | eff. | 1 17 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | do. | | 1.16 |
| 114 | *Biddle*..... | 167 | 157 0 | 16 2½ | ... | ... | 4 7½ | 56.8 | .659 | .478 | .724 | .743 |
| | | 168 | ... | ... | 4 8½ | 4 11½ | 4 10 | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.16 |
| 115 | *Blakely*..... | 166 | 175 1½ | 16 10½ | ... | ... | 4 8 | 63.4 | .604 | .375 | .648 | .769 |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 116 | *DeLong*..... | 166 | 175 1½ | 16 10½ | ... | ... | 4 8 | 63.4 | .604 | .375 | .648 | .769 |
| | | 191.6 | ... | ... | 4 11 5/16 | 6 6½ | 5 9 3/32 | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 117 | *Shubrick*..... | 165 | 175 0 | 16 8 | ... | ... | 4 8 | 72 | .523 | .389 | .73 | .75 |
| | | 188.5 | ... | ... | 4 7½ | 6 11½ | 5 9½ | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.16 |
| 118 | *Stockton*..... | 165 | 175 0 | 16 8 | ... | ... | 4 8 | 74 | .523 | .399 | .73 | .75 |
| | | 197 | ... | ... | ... | ... | 5 11 | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.16 |
| 119 | *Thornton*..... | 165 | 175 0 | 16 8 | ... | ... | 4 8 | 71 | .521 | .383 | .73 | .75 |
| | | 185 | ... | ... | 4 7½ | 6 11½ | 5 9½ | ... | Wa | ke co | eff. | 1.213 |
| | | ... | ... | ... | ... | ... | ... | ... | | do. | | 1.16 |
| 120 | *Wilkes* ..... | 165 | 175 0 | 16 8 | ... | ... | 4 8 | 78 | .513 | .402 | .73 | .75 |
| | | 200 | ... | ... | 4 11 | 7 0½ | 5 11 5/16 | ... | ... | ... | ... | ... |
| | | ... | ... | ... | ... | ... | ... | ... | Wa | ke co | eff. | 1.16 |

*a*. Trial results.....*b*. Proposed screw.....*d*. Mean pitch.

OF U. S. NAVAL VESSELS.

| Performance. | | | Propellers. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Speed. | Revs. | I.H.P. | Number. | Blades. | D. | P. | $\frac{P}{D}$ | Hel. area. | Proj. area. | $\frac{\text{Hel. area}}{\text{Disc. area}}$ | App. slip. | Effic. | Ind. thrust per sq. ft. Hel. area. | Ind. thrust per sq. ft. Proj. area. | Remarks. |
| *knots.* | | | | | *ft. ins.* | *ft.* | | | | | | | | | |
| 22.5 | 410 | 1,750 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 24 | 451.9 | ... | .. | .. | 4 8 | 6.22 | 1.33 | 6.9 | 5 28 | .403 | 13.5 | ... | ... | ... | *a,f.* |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 20 | 350 | 850 | 1 | 4 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 20.11 | 391.1 | ... | .. | .. | 5 3 | 6.75 | 1.28 | 11 | 8.5 | .508 | 22.8 | ... | ... | ... | *a,f.* |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 20 | 350 | 850 | 1 | 4 | ... | ... | ... | ... | ... | .. | ... | ... | ... | ... | |
| 19.82 | 370 | ... | .. | .. | 5 3 | 6.58 | 1.25 | 11 | 8.5 | .508 | 17.2 | ... | ... | ... | *a,f.* |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 30 | 400 | 7,200 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 7 8 | 8.5 | 1.1 | 21.75 | 17.5 | .471 | 16 | ... | ... | ... | *e,d.* |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 30 | 360 | 5,850 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 7 4 | 9.99 | 1.36 | 16.95 | 12.6 | .4 | 8 9 | ... | ... | ... | *f.* |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 30 | 400 | 5,600 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 30.88 | 422 | ... | .. | .. | 6 10 | 9.125 | 1.33 | 16.42 | 11.44 | .451 | 18.74 | ... | ... | ... | *a,f.* |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 28 | 320 | 4,200 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 29.15 | 309.12 | 3,920 | .. | .. | 6 8 | 10.86 | 1.62 | 14.7 | 10 | .42 | 12.2 | 65.2 | 1,311 | 1,926.7 | *a,f.* |
| 29.15 | 312.31 | 3,920 | .. | .. | 6 8 | 11.21 | 1.68 | 14 7 | 9.8 | .42 | 10.5 | 64.2 | 1,256 | 1,871 | *b.* |
| 28 | 320 | 4,200 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 29.04 | 312.31 | 3,910 | .. | .. | 6 8 | 10.86 | 1.62 | 14.7 | 10 | .42 | 13.1 | 65.2 | 1,294 | 1,909 | *a,f.* |
| 29.15 | 312.31 | 3,920 | .. | .. | 6 8 | 11.21 | 1.68 | 14.7 | 9.8 | .42 | 10.5 | 64.2 | 1,256 | 1,873 | *b.* |
| 28 | 320 | 4,200 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 28.51 | 306.7 | 3,650 | .. | .. | 6 8 | 10.86 | 1.62 | 14.7 | 10 | .42 | 13.2 | 65.2 | 1,230 | 1,808 | *a,f.* |
| 29.15 | 312.31 | 3,920 | .. | .. | 6 8 | 11.21 | 1.68 | 14.7 | 9.8 | .42 | 10.5 | 64.2 | 1,256 | 1,873 | *b.* |
| 26 | 350 | 3,000 | 2 | 4 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 25.49 | 371.45 | ... | .. | .. | 5 6 | 8.925 | 1.62 | 11.52 | 7.33 | .485 | 22.02 | ... | ... | ... | *a,f.* |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 26 | 350 | 3,000 | 2 | 4 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 25.52 | 360.4 | ... | .. | .. | 5 6 | 8.925 | 1.62 | 11.52 | 7.33 | .485 | 25.2 | 68.9 | ... | ... | *a,f.* |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 26 | 350 | 3,000 | 2 | 3 | ... | ... | .. | ... | ... | ... | ... | ... | ... | ... | |
| 26.22 | 365.8 | 3,275 | .. | .. | 5 8 | 9 | 1.59 | 10.38 | 7.59 | .411 | 20.06 | 66.2 | 1,582 | 2,163 | *a,f.* |
| 27.57 | 392.6 | 3,576 | .. | .. | 5 8 | 9 | 1.59 | 10.85 | 7.94 | .43 | 20.9 | 67.5 | 1,539 | 2,103 | *b.* |
| 26 | 350 | 3,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 25.88 | 358 | 3,218 | .. | .. | 5 8 | 8.95 | 1.58 | 10.24 | 7.59 | .411 | 18.8 | 66.2 | 1,618 | 2,163 | *a,f.* |
| 27.57 | 392.6 | 3,576 | .. | .. | 5 8 | 9 | 1.59 | 10.85 | 7.94 | .43 | 20.9 | 67.5 | 1,539 | 2,103 | *b.* |
| 26 | 350 | 3,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 27.57 | 392.6 | 3,576 | .. | .. | 5 8 | 9 | 1.59 | 10.3 | 7.59 | .411 | 21.26 | 66.2 | 1,604 | 2,200 | *a,f.* |
| 27.57 | 392.6 | 3,576 | .. | .. | 5 8 | 9 | 1.59 | 10.85 | 7.94 | .43 | 20.9 | 67.5 | 1,539 | 2,103 | *b.* |
| 26 | 350 | 3,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 25.99 | 396.6 | ... | .. | .. | 5 6 | 8.67 | 1.58 | 10.41 | 7.43 | .438 | 23.4 | ... | ... | ... | *a,f.* |
| 27.57 | 392.6 | 3,576 | .. | .. | 5 8 | 9 | 1.59 | 10.85 | 7 94 | .43 | 20.9 | 67.5 | 1,539 | 2,103 | *b.* |

*e.* Pitch axially and radially expanding.....*f.* True screw.

SCREW PROPELLERS

| Reference No. | Name of vessel. | Displacement. | Dimensions. | | | | | Area immersed midship sect. | Hull coefficients. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Length L.W.L. | Beam. | Draft, for'd. | Draft, aft. | Draft, mean. | | Cyl. | Extr. dim. | Mid-ship sec't. | L.W. plane. |
| | | | *ft. ins.* | *ft. ins.* | *ft. ins.* | *ft. ins.* | *ft. ins.* | *sq. ft.* | | | | |
| 121 | *Tingey*..... | 165 | 175 0 | 16 8 | ... | ... | 4 8 | 71 | .465 | .437 | .73 | .75 |
| | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | ... | ... | ... | ... | ... | ... | ... | ... | Wake coeff. | | | 1.16 |
| 122 | *Nicholson*..... | 174 | 174 6 | 17 0 | ... | ... | 4 6 | ... | ... | .475 | ... | ... |
| | ... | ... | ... | ... | ... | . | ... | ... | ... | ... | ... | ... |
| | 219 | ... | ... | ... | ... | ... | ... | ... | Wake coeff. | | | 1.16 |
| 123 | *O' Brien*..... | 174 | 174 6 | 17 0 | ... | ... | 4 6 | ... | ... | .475 | ... | ... |
| | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| | 219 | ... | ... | ... | ... | ... | ... | ... | Wake coeff. | | | 1.16 |
| | | | | | | | | | SCREW PROPELLERS OF | | | |
| 124 | *Drake*..... | 14,100 | 500 0 | 71 0 | 26 1½ | 26 1½ | 26 1½ | ... | ... | ... | ... | ... |
| | ... | ... | ... | ... | ... | ... | ... | ... | Wake coeff. | | | 1.08 |
| | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 125 | *Good Hope*..... | 14,100 | 500 0 | 71 0 | 26 1½ | 26 1½ | 26 1½ | ... | ... | ... | ... | ... |
| | ... | ... | ... | ... | ... | ... | ... | ... | Wake coeff. | | | 1.134 |
| | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 126 | *Leviathan*..... | 14,100 | 500 0 | 71 0 | 26 2 | 26 1½ | 26 1½ | ... | ... | ... | ... | ... |
| | ... | ... | ... | ... | ... | ... | ... | ... | Wake coeff. | | | 1.075 |
| | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| 127 | *King Alfred*..... | 14,100 | 500 0 | 71 0 | 26 1½ | 26 1½ | 26 1½ | ... | ... | ... | ... | ... |
| | ... | ... | ... | ... | ... | ... | ... | ... | Wake coeff. | | | 1.035 |
| | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |

*a*. Trial results.....*b*. Proposed screw.....*c*. Blades set as cast.....*d*. Mean pitch.

OF U. S. NAVAL VESSELS.

| Performance. | | | Propellers. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Speed. | Revs. | I.H.P. | Number. | Blades. | D. | P. | $\frac{P}{D}$ | Hel. area. | Proj. area. | Hel. area / Disc. area | App. slip. | Effic. | Ind. thrust per sq. ft. Hel. area. | Ind. thrust per sq. ft. Proj. area. | Remarks. |
| *knots.* | | | | | *ft. ins.* | *ft.* | | | | | | | | | |
| 26 | 350 | 3,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 6 3 | 9.375 | 1.5 | 14.37 | 10.3 | .468 | ... | ... | ... | ... | *f.* |
| 27.57 | 392.6 | 3,576 | .. | .. | 5 8 | 9 | 1.59 | 10.85 | 7.94 | .43 | 20.9 | 67.5 | 1,539 | 2,103 | *b.* |
| 26 | 350 | 3,500 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 6 5 | .33 | 1.61 | 16.2 | 11 5 | .5 | ... | ... | ... | ... | *e,d.* |
| 26 | 350 | 4,080 | .. | .. | 6 5 | 9.3 | 1.43 | 13.93 | 10.48 | .43 | 19.06 | 66.8 | 1,485 | 1,973 | *b.* |
| 26 | 350 | 3,500 | 2 | 3 | ... | ... | ... | ... | ... | .. | ... | ... | ... | ... | |
| ... | ... | ... | .. | .. | 6 5 | 10.33 | 1.61 | 16 2 | 11.5 | .5 | ... | ... | ... | ... | *e,d.* |
| 26 | 350 | 4,080 | .. | .. | 6 5 | 9.3 | 1.43 | 13.93 | 10.48 | .43 | 19.06 | 66.8 | 1,485 | 1,973 | *b.* |
| BRITISH ARMORED CRUISERS. | | | | | | | | | | | | | | | |
| 23 | 120 | 30,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 24.11 | 122.4 | 31,409 | .. | .. | 19 0 | 23 | 1.21 | 105 | 82.7 | .37 | 13.22 | 68.4 | 1,753 | 2,226 | *f,e,g.* |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 23 | 120 | 30,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 23.05 | 126.2 | 31,088 | .. | .. | 19 0 | 22.75 | 1.197 | 76 | 60.3 | .27 | 18.6 | 69 | 2,381 | 2,963 | *f,e,g.* |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 23 | 120 | 30,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 23.23 | 121 | 31,208 | .. | .. | 19 0 | 23.75 | 1.25 | 76 | 60 | .27 | 17.8 | 69 | 2,366 | 2,997 | *f,k,g.* |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 23 | 120 | 30,000 | 2 | 3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 23.46 | 118.8 | 30,893 | .. | .. | 19 0 | 23.75 | 1.25 | 76 | 60 | .27 | 15.7 | 69 | 2,377 | 3,011 | *f,k,g.* |
| ... | ... | ... | .. | .. | ... | ... | ... | ... | ... | ... | ... | ... | .. | ... | |

*e.* Pitch radially and axially expanding.....*f.* True screw.....*g.* Performance.....*k.* Blades cast for 22 feet 9 inches pitch.

# ON THE EFFECT OF MODERN ACCESSORIES ON THE SIZE AND COST OF WARSHIPS.

By W. H. Whiting, Esq., Member,

Assistant Director of Naval Construction, R. N.

[Read at the Spring Meeting of the Forty-fourth Session of the British Institution of Naval Architects, April 1, 1903.]

---

In limiting the title of this paper to warships, I do not wish to suggest that the influence of these matters on the size and cost of merchant ships is negligible; but only that in most cases it is relatively less, so that a discussion of its nature and extent would be, for this reason as well as for others to be set forth later, of far smaller importance.

By modern accessories I mean those features which have been introduced into warships, especially during the last twenty years, at such a rapid rate, but which are not specifically designed for and necessary to the main object of the vessel's existence—the overpowering and destruction of the enemy in the day of battle. For this end, seaworthiness, structural strength, habitability, speed, coal supply, gun power and protection are essential; they are, at least, features of primary importance. They will be regarded as generally indispensable for battles on the high seas such as have decided the fate of nations; but there are, in every large warship, hundreds of features which are not, like these, of primary importance. They add to the appearance, or convenience, or even to the efficiency of parts of the ship, but they can hardly be said to be indispensable. They affect, perhaps, the facilities for navigation or other wants of ordinary peace work. Sometimes they increase the efficiency of the primary features named above, though they are not absolutely necessary to their existence. They often provide against risks, more or less remote, of accident or breakdown in peace or war. Many are due to the

general rise in the standard of comfort in life ashore, and to the many modern inventions which have made this comfort possible. But, whether taken singly or all together, it cannot be said that they are essential to the supreme end for which the Navy is maintained.

There is, as one might expect, great difference of opinion as to the importance or the necessity of these matters. As regards many of them, there would be found on detailed inquiry a general opinion that they ought to be retained. As regards many others, various conclusions would be arrived at, according to the experience, or the calling, or the temperament of the individual, and according to his appreciation of the convenience afforded or the risk avoided by each item. In some cases a landsman might reasonably form a judgment about them; in many others only a naval officer could well do so. I shall offer no opinion about any of them. I desire only to show that they exist, to try to classify them, to name some of the principal causes which originate and maintain them, and to point out and emphasize the consideration which is common to them all—that they have to be paid for. The payment may be mainly in cost, or it may be—it generally is—in increased size of ship as well, and in decrease of speed or offensive power or protection. It may be in ways less evident, though not less certain or exacting. In whatever form it be, the payment has to be made, and the price, I fear, is not generally known.

It is more easy to understand how the influence of a number of subordinate items escapes adequate notice, when we recall the discussions in the early years of this Institution respecting fighting ships. It was not unusual in those days to hear demands for an ideal vessel—heavily armed, thickly armored, with high speed and a big coal supply, but of small dimensions. Many years passed before that mythical vessel disappeared. There are still to be met with lingering traces of a belief in her. But the impossibility of securing all these qualities in one small ship is now realized. It is seldom contested that if you take a given design, or ship, and put, say, more guns into her, you must accept less coal, or armor, or speed. The proposition that a

ship is a compromise in regard to these important features is well established. Unfortunately, it is not equally well understood that the matters of which I speak have a cumulative effect on the ship equal to a large variation in one of her principal features; and even where there is an acceptance of this general statement in the abstract, there may be no small difficulty in securing its application to the particular case in hand.

The effect on the whole design of a substantial variation in one of the principal qualities of a ship has often been investigated. It is well known that if you add to the weight of the armor, or coal, or guns by a certain definite amount, and if every other quality of the ship, save this one has to be maintained unimpaired, the result will be a total increase of weight, size and cost which far exceeds the original increment. If, for instance, in order to increase the speed, you add 100 tons to the weight of the machinery, there will follow in general such increased weights of hull, equipment, coal and armor as will add perhaps 300 tons or more to the displacement. It is, of course, equally certain that a number of lesser items, whose weight amounts in all to 100 tons, will likewise involve an increased displacement of much more than 100 tons.

It would be traveling outside the proper scope of this paper to show in detail how variations of equal amount in the weights of primary features of a design have, in the above conditions, such different effects on the design; or how variations of a constant percentage in the same primary features may produce, in designs not of the same type, widely different results. It may be mentioned, however, that the chief factor in determining the effect of such a variation is the space it demands considered in reference to the demands on space in the existing ship. Thus, an increase in thickness of armor in a battleship, and an increase in speed in a small cruiser—keeping all other qualities constant in each case—represent, perhaps, opposite extremes in regard to the relative change produced in the design. Considerations of the same character govern the effect on a design of the matters of which this paper treats.

I do not propose to examine a number of specific instances

of the influence of such features in existing classes of ships. There are obvious objections to such a course. But while it is hardly practicable to prove in detail how important these seemingly unimportant items are, I will mention two examples which will illustrate the general proposition. The first is that of the steamboats carried by a warship, or, more strictly speaking, the weight of the largest steamboat. Until twenty years ago, the weight of the largest steamboat carried by most vessels was about 9 tons. This boat—a 37-foot steam pinnace—could be hoisted at davits by hand, and the only fittings required were the davits themselves and their usual accompaniments, the boats' falls, and perhaps crutches. But the size of steamboats has been increased until most of our large battleships and cruisers carry two 56-foot steam pinnaces, each weighing 18 tons. Following the introduction of these boats, we have had one, and generally two, masts of great strength, with corresponding shrouds, and a 60-foot derrick with massive head and heel castings, 6½-inch steel wire purchases and topping lifts, 25-inch blocks, eyeplates at mast head and on deck tested to 60, 70 and even 90 tons each, two steam boat hoists with beds, casings, steam pipes, &c., skid beams and boats' crutches for stowing the boats in-board, hull structure for supporting the masts, stores necessary for the maintenance of these fittings, and, lastly, alternative gear for hoisting the boats by hand.

In this case the replacement of two 9-ton boats by two 18-ton boats means an addition, not of 18 tons, but of at least 70 tons to the weight carried. To carry this load without loss of speed or other qualities an addition to the displacement considerably exceeding 70 tons will be necessary. I express no opinion as to the need for these boats. They are far superior to the older boats in speed and seaworthiness, though these indeed served for many years in the same harbors. They have, too, increased fighting powers as boats. But I class them as minor matters, because it is not generally supposed that they and their accompaniments will have much influence on a fleet action of to-day, except as débris. They offer an excellent example of the numerous additions which follow a single change.

A corresponding result may be brought about in another way. Instead of increasing the magnitude of some particular item, you may develop it with the object of increasing its efficiency or of lessening the chance of a breakdown. An example of the great weight involved in such an elaboration of a set of fittings for a single purpose is afforded by the anchor and cable gear in a ship. In many merchant steamers we find what may be taken as the minimum provision which is compatible with safe navigation. These vessels carry stockless anchors which require no special stowage. Their cables come in through open hawse pipes to a windlass, and pass straight into the lockers immediately below. They ride by the windlass. No other fittings are supplied except, perhaps, bow stoppers at the upper end of the hawse pipes.

If we compare these rudimentary fittings with what is found in most existing battleships and cruisers, the difference is very striking. The hawse pipes have hinged flaps on the outside, and hawse plugs and hinged flaps as well at the inner end. Each of these three sets of gear is adapted for fitting over the cables, and the outer flaps are closed by special screws working through the body of the hawse pipes. The anchors have hitherto been stocked, and this has necessitated beds with numerous appliances for securing and letting go. There are massive catheads, which are hinged to turn down for action, and need special appliances to get them up again. Immediately abaft the hawse pipes come the bow stoppers, and next to them a manger board with further fittings for excluding water. Along the deck there are several stopper bolts with cable stoppers, some of which are nearly equal to the strength of the cable. Then there are large riding bits as well. Following these three or four sets of gear for holding the cable, there are the cable holders proper above the deck, and the compressors below, each capable of serving the same purpose. The cableholders for the two bower cables are arranged for hauling with one cable and veering with the other, or *vice versa*, or for hauling or veering both cables simultaneously. One cableholder is arranged to work the sheet cable as well. Then, as a stand-by, the middle line capstan, which works the cat

chain or wire, is also fitted to bring in either of the lower anchors or the sheet. Immediately under the upper deck are the heavy lever compressors, with purchases, eyeplates, and cleats for working them. To provide for the cable running out either round the windlass or round the bits, these compressors are made of spectacle form, so as to act equally well in either direction. The capstan can be worked by hand as well as by steam, and gearing is provided to work the windlasses also in this manner. Besides all these fittings there are numerous special appliances. To enable the ship to ride conveniently with two anchors down she has heavy mooring swivels, which necessitate the hawse pipes being big enough to take three parts of the cable side by side. The chain lockers are usually two or three decks down, and the heavy deck pipes have watertight covers and bucklers for fitting over the cable if in place. The capstans have watertight glands on each deck. The large rollers round capstans are bushed. The catheads have locking gear, besides the tackles fitted for holding them in position. And many other fittings add to the provision which is made for every emergency or risk.

I say again, I offer no opinion as to the usefulness of each and all of these fittings. My point is that most of it is not of primary importance in the sense in which these words are defined above, and that for a ship of given dimensions the fitting of this elaborate apparatus (which indeed goes beyond my description) must necessarily exclude many tons of armor, armament, or machinery, or in the alternative must involve several times as great an addition to the total displacement.

It will not be supposed, of course, that I am naming cases which have been in any way overlooked. It is well known that stockless anchors are being fitted in most of the cruisers and battleships now building. The question of steamboats is also one to which it is not necessary to call attention. I have intentionally chosen two cases which, though found in most ships afloat, do not exist as here described in the latest Navy practice.

These are two somewhat striking instances of the magnitude which such fittings may attain. There are scores, perhaps hundreds, of similar though less conspicuous cases to be found in

most ships of war. We find in one set of instances that, starting from what is demanded by the bare necessity of the case, we have added largely to the weight and cost to secure additional efficiency or convenience. In the second set we have added weights to provide against secondary or even more remote risks. The first group includes the lengthening of funnels; the raising of machinery cowls and ventilators with their elaborate gear; the provision of stowage for every article in the ship—often of duplicate stowage; the special contrivances for watertightness in weather work and in electrical fittings; and the great elaboration of drainage. The second includes such instances as the various kinds of apparatus for working the cables, the provision for steering from different places by various means, the use of automatic valves, and of special pumping, flooding and ventilating appliances.

If one were to attempt to lay a complete list before you it might perhaps be thought that some of the items are so small that a reduction in their weight is hardly worth making. One often hears it said: "What will you save—not a hundredweight?" Or it may be that even a smaller figure is named. But it is obvious that a small percentage on a large number of items may give quite an appreciable result; and very often the percentage is a large one, though the absolute weight concerned is but little. Further, each saving has to be multiplied by two or three to get its gross effect on the ship. And lastly, the real question is: "What can be added by such savings to the armament, or to some other primary feature of the ship?"

Take for example a 9,000-ton cruiser, whose hull weighs, let us say, 3,500 tons, her machinery 1,600 tons, and her armament 700 tons. Now, supposing even that on the greater part of her hull structure proper and of her machinery no great saving is possible, yet if we can save 5 per cent. on 2,000 tons we have 100 tons, and this is 14 per cent. on the armament weights. It may be a very fair subject for inquiry whether the additional 5 per cent. of hull and machinery weights will be worth as much as the 14 per cent. of armament when the vessel goes into action. And if you go round a ship and carefully examine the weights

in detail, there are a very large number on which you can conceivably save 5 per cent. There are fewer than one might at first suppose which are not capable of an economy of 5 per cent.

Sometimes, of course, you can reduce the weight of fittings by more careful design alone. It needs to be made clear, however, that you cannot always do so. Such savings can only be got in many cases by sacrificing something which admittedly adds to efficiency in a minor sense. This is inevitable. You cannot get something for nothing, or, if you do, it is not worth having. Yet it is not always understood that economy in these matters often means giving up something that you want and not merely something that you do not want. It is hardly to be supposed that there will be found in a modern vessel many things that are absolutely useless.

The main question in any given design is whether there have been selected and combined the most advantageous qualities which can be got on a given displacement and for a given price at that moment. If we have it, it is a successful design. If we have materially sacrificed qualities which will certainly be needed at the beginning of an action to provide for risks which may occur at its close, or for other remote contingencies, then the presumption is that there is a more satisfactory design possible. It is often the case that those who appreciate the advantages of the little efficiencies in detail, nevertheless fail to recognize why the completed vessel compares unfavorably as to her fighting qualities with a ship from which such fittings have been more rigorously excluded.

Many causes have worked together to affect a modern warship in this way; many are still in operation; and I wish to devote my remaining time to a brief summary of those which can well be brought before this Institution.

### RETENTION OF THE USELESS SAILS, ETC.

(1.) The natural tendency in any large organization is to retain things which have come to be of less use than formerly, or even of no use. From this tendency navies are not exempt, and we find fittings and stores retained which might possibly be omitted

with advantage. The strong feeling in favor of the retention of sails long after these had ceased to be of use, and had even become a danger, is an illustration of this tendency.

LABOR SAVERS DO NOT REDUCE CREWS.

(2.) The rapid development of mechanical improvements of every kind leads to the introduction of labor-saving appliances in warships and merchant ships alike. But, whereas these are accompanied by great reductions in the crews of merchant ships, it is necessary to keep big crews in warships for fighting purposes, and thus we get on the one hand steam pumps to save daily manual pumping of fresh water or of the bilges, and on the other hand special fittings for exercising purposes.

LUXURY.

(3.) The higher standard of life ashore and afloat adds rapidly to the weights of warships. The provision for food, cooking, bath-room and sanitary fittings, ventilation and artificial light has greatly increased in the last twenty years and is still increasing. A large proportion of the complement needs superior accommodation, corresponding with their higher training. The weights of tiling and of piping for hot and cold water are vastly greater than those that served for many ships which are still in commission.

COAL FOR LUXURIES.

(4.) The steam or electric motors used for the purposes of the last two paragraphs involve a heavy coal bill, so that to give a ship a specified steaming capacity it is necessary to add a much larger percentage of coal than formerly. This load has to be carried at the given speed.

DUPLICATION OWING TO DISTRUST.

(5.) The distrust (or rather the partial trust) of new appliances adds largely to weight and cost. Candles or lamps give place to electric light, but the fear of losing the light involves the carrying of two systems instead of one. So it has been with sail and steam power, steam and hand steering, hydraulic gun gear and

hand gear. And as it is but rarely that the new appliance has an advantage in every conceivable circumstance over the old there is a great tendency to carry both. In almost every case such duplication involves some new chance of a breakdown; and this serious consideration applies also to the two following paragraphs. New risks, thus introduced, have brought about many accidents in recent years.

DUPLICATION—EVEN TO QUINTUPLICATION.

(6.) A natural desire to provide for every risk leads to great increase in detail. Thus many vessels used to have five different methods of operating the steering gear. The anchor and cable gear, the ventilation, drainage and pumping arrangements had, and still have, great elaboration. It is, of course, very difficult to so accurately appraise a particular risk as to say that it is not worth providing against. It is still less possible to provide for it without making the ship as a whole suffer to a certain definite extent.

MULTIPLICATION OF FITTINGS.

(7.) A closely-allied tendency is that which leads to the duplication of fittings. Thus there are two steering engines, or two leads of shafting to operate the steam steering engines; the dynamos are designed so that one may always be under repair or idle, and each of the hydraulic pumping engines is equal to the whole demands of the armament. Here, too, the cause of the demand for the increased weight is the difficulty of saying exactly what risk should be expected. The logical course would be to make provision proportional to the magnitude of the risk multiplied by its probability. It is possible that in some cases an appropriate valuation might be obtained by careful study, and I would like to suggest that no small service might be rendered to the Navy by an examination of this question.

CREATURE COMFORTS.

(8.) A great source of increased weight is the additions called for by comfort and convenience, rather than by direct necessity.

Thus bigger steamboats, better artificial lighting, double or rain awnings, side screens, wind shoots, ice machines, etc., though each of undoubted utility, and though reaching in no way beyond the standard of comfort in passenger steamers, do, nevertheless, impose a considerable load, direct and indirect, on a warship.

OVER-PAINTING SMARTNESS.

(9.) The desire, and perhaps the necessity, for smartness adds largely to weight. First and foremost in this connection comes paint. One who has not the records before him may well be incredulous at the enormous weight of paint worked into a ship. The most serious feature is that the process never ceases, and the greater the pride in the ship the greater the tendency to sink her with white lead. I have been told of a case in which there was removed, from the inner surface of a portion of the crew space of a destroyer, paint of a weight of over 2 pounds per square foot. This is no doubt, exceptional, but I doubt whether all officers realize how, by a rigid economy in paint, they may not inappreciably benefit their ship.

HIGH-STRUNG SMARTNESS—SCREW RIGGING.

A curious development of this wish for smartness is the desire for screw gear on board ship. Not merely in rigging, but in many fittings, such as awnings, ridge-ropes, guard chains and ropes, and in the securing of all kinds of gear, lashings have given place to screws and slips, which not only add directly to the weight, but impose greater strains on the fittings. The screws mean bigger awning stanchions, and so on.

FLEET COMPETITION.

(10.) Auxiliary machinery tends to be continually increased in power by the competition of fleet life. Weighing anchor, laying out anchors, and other operations carried out in concert lead to the working of gear for all it is worth, and to demands for more power, although the direct use in war may not be great.

TACTICAL DEVICES—TORPEDO NETS.

(11.) Any doubt as to tactics, whether of defense or offense, must inevitably add to weight. Thus the torpedo-net defense, now rarely carried by fast cruisers, formed a big load in earlier vessels. Similarly, questions as to the positions of searchlights, the use of fighting tops and of submarine mines have had the like tendency. There is a larger sense in which this consideration affects ships. If it could be exactly and permanently determined in what way a fleet should be used, great economies in design would no doubt be possible. It might conceivably lead to greater specialization, so that a squadron, not necessarily homogeneous as to offense or defense, should become the unit of design. The extended use of auxiliaries might tend to ease many difficulties in the design of a single fighting ship.

HEAVY FITTINGS.

(12.) The greater demand for perfection in fittings has led to increased weight in recent years. This applies particularly to such matters as watertightness in skylights, ports, casings and electrical fittings. No one who compares the fittings of two ships whose age differs by ten years or more can fail to see the additional weight of fittings due to this cause.

HIGH-PRESSED MACHINERY.

(13.) A desire not to press machinery severely imposes a great load on a ship compared with another in which such pressing is admissible. If this consideration extend not merely to the boilers, but to the many pieces of auxiliary machinery throughout the ship, the effect is very appreciable.

MORE AND NOT LESS LUXURY.

(14.) Daily life in a ship tends to call attention far more to what is felt to be lacking than to what is redundant, and hence in a ship, as in a house, there is a constant tendency to add new fittings at a higher rate than to dispense with others.

DESIRE FOR EXCESSIVE DURABILITY.

(15.) Desire for great durability may unduly increase the first cost and size of a ship. It is possible that it may pay better to accept frequent repairs than to add to scantlings and weight.

ACCESSORIES GETTING HIGHER ABOVE C. G.

(16.) The general tendency to raise important parts of the vessel in relation to the water line makes it ever more difficult to secure adequate stability, and this involves increased dimensions. Economies tend to be made in the lower parts of the ship. Additions are more often high up.

ONE ACCIDENT ADDS WEIGHT TO ALL SHIPS.

(17.) Every accident to a ship leads to demands for mechanical provision in all other ships to meet or prevent such a case, although the chance of its recurrence be small, or the accident due to personal causes.

These are, I believe, some of the principal causes which tend to increase the weight of warships. Some others might be named, but they do not, like these, spring from general considerations, and they could not well be discussed here.

Some of these factors exist in merchant ships, but there is one radical difference between the Mercantile Marine and the Navy. In the latter the test of experience is largely wanting. If from any cause there be imposed on a merchant ship unnecessary loads or superfluous cost, there is an immediate and automatic check. She does not pay. Somebody else's ships pay better. Dividends are the touchstone of efficiency. Nothing of the kind exists in any practical shape in regard to warships. You cannot test them by setting them to fight one another, and paper valuations are a poor substitute.

But, though the keenness of the competition in the case of fighting ships be less evident and its realization be delayed, it is none the less real. Its very intensity makes these minor matters of design things of moment. It constitutes the best of reasons for saving small weights and for accepting small risks. Wherever we get similar conditions, as in the international race for the

*America* Cup, we find the same necessity for scrupulous design, involving the rejection of all fittings not needed for the decisive race, and the acceptance of minor risks of breakdown. It is interesting to note in the latter connection that the margin of safety is sure in such a case to be very small. The accidents to the *Shamrock* did not show a mistaken policy in the design, but proved how great was the necessity for the avoidance of unnecessary strength. You could as certainly secure the loss of the race by a few additional precautions against breakdown, such as making your spars or rigging somewhat too heavy as by making them too light. Precisely the same thing is true respecting a closely contested struggle between well-matched naval powers. War is a great risk—the greatest of risks. To try to make it safe is to secure beyond possibility of doubt that it shall be fatal. Not the avoidance of, but the equalization of, risk is the criterion of good design.

It has sometimes been suggested that there is no harm in making a ship somewhat bigger than is necessary for the satisfaction of the main conditions of the design. The saving of small weights is looked on as unnecessary stinginess. This line of thought ignores the fact that the weight involves cost. All the arguments I have tried to lay before you are immensely strengthened when we reflect that these additional weights nearly always impose an expenditure of money in greater proportion than that of weight. Improvements are generally expensive. You make a machine 10 per cent. more costly without making it 10 per cent. heavier. You sometimes do both without making it 10 per cent. more efficient.

These objections to economy ignore also the loss of time. Given two designs, in one of which there is a marked increase in elaboration and complexity of detail, and you will increase the time of building faster than the weight or, perhaps, than the cost. Speed of construction is an important element of the naval strength of the country. It increases the available force at any moment, and leaves our building resources available for fresh work. Elaboration does precisely the opposite. It takes from

the primary features of each ship. It lessens the number of ships to be got for a given sum. It delays their production.

Lastly, in the ceaseless accumulation of these accessory features of warships we have one of the chief factors in their general deterioration. Their armament, armor and machinery tend to fall behind as improvements in manufacture and design follow one another in rapid succession. This is, of course, inevitable. But nothing so surely tells against a ship as the continued process of sinking her. The history of many ships, as recorded by their draughts from year to year, affords conclusive proof that the growth of minor details amounts in the aggregate to a large variation in a principal feature of the design.

If we had reason to suppose that the contest for naval supremacy in the immediate future would be mild and unimportant, or one in which we should have little cause for sustained national effort, it might still be possible that the subject of this paper would be worthy of the attention of this Institution as an interesting problem in naval design. But not many will, I think, say that the matter is one of only academical interest. As the pressure of mercantile competition and maritime interests grows greater, it is certain that this country will have to put forth corresponding effort to keep her place as the greatest of naval powers. It will be dangerous to neglect even small sources of advantage. It may be equally so to suppose that we can permanently face a greater outlay than others for the same unit of naval force. There are signs that there is being applied elsewhere a more rigorous analysis to the methods as well as to the history of naval power. Every improvement in armor, in ordnance or in structural material will be of value; and these minor matters will afford yet another field for advance, equal in importance to some of those more obvious once.

But it is also a field in which advance is very difficult. So many things militate against economy. It is rarely a thing about which one grows enthusiastic. There is much discouragement with it, and some little risk. But the work is there, and has to be done; and it can only be done by the united efforts of all connected with the Navy. It is by no means merely a question

of office design. It needs the intelligent and ceaseless co-operation of all engaged in the work of construction, and not least that of our subordinate building officers and workmen. Most of all, it needs the continuous help and often the thought and self-denial of naval officers of all ranks, who necessarily exert so great an influence on the details of the ships they have to live in and to fight.

It is well known to many here that this subject is not a novel one. It has engaged the attention of those who direct the affairs of the Navy. Much has been done, but it is a work in which much more still remains. It is with the object of attracting more general attention to the practical side of the question that this paper has been prepared.

# SPEED AND COAL-CONSUMPTION CURVES.

By Lieut. Daniel S. Mahony, U. S. N., Member.

The subject of coal consumption at various speeds, and the importance of securing graphic curves to represent the relation existing between coal consumption and speed of various classes of warships, was so ably handled by Professor Ira N. Hollis in his articles published in Vols. IV and V of the Journal of the American Society of Naval Engineers, that it was with some reluctance that the writer was induced to take up this question.

By reason of the fact, however, that there is now available an extremely large amount of valuable data that was not accessible to Professor Hollis, it ought to be possible to develop graphic curves showing the exact relations between coal consumption and speed that would be much more applicable to existing conditions. Such curves could be of great convenience and benefit to commanding officers, in that they would add to their knowledge of the efficiency and capability of the motive power, and likewise give positive information as to the steaming radius of the respective vessels at varying speeds.

In his discussion of Professor Hollis' article on Economical Speed and Coal Endurance of Warships, etc., Volume V, page 66, Journal American Society of Naval Engineers, ex-Engineer-in-Chief Isherwood says:

"Take from the log of the performance of any given vessel all the data for speeds between, say $6\frac{1}{2}$ and $7\frac{1}{2}$ knots, and consider the mean as the data for the speed of 7 knots. In like manner take all the data for speeds between $7\frac{1}{2}$ and $8\frac{1}{2}$ knots, and consider the mean as the data for the speed of 8 knots, and so on up to the highest speed, advancing by increases of 1 knot. There would thus be obtained the consumption of coal in pounds per hour due to all uses corresponding to these speeds, which weight of coal, divided into the total number of pounds carried in the

bunkers, gives the number of hours steaming at the speed taken, and this number, multiplied by the speed, gives the distance the vessel will pass over with the total weight of coal carried in the bunkers. This is the most direct, sure and simple method of ascertaining the most economical speed. If the speeds of the vessel be laid off by scale, as abscissae on a straight line, and if, on ordinates erected from these abscissae at right angles to the line, there be laid off by scale the corresponding consumption of coal, a graphic curve passed among the free ends of the ordinates so as to leave as many on the one side as on the other would serve as a formula of interpolation, from which the coal consumption for any speed between the experimental limits could be obtained. The other data, such as the number of revolutions made per minute by the screw, the various steam pressures, vacuum, temperatures, etc., etc., should be similarly obtained and recorded. If the cruising thus digested has been considerable, the differences due to wind and wave, cleanliness of the bottom of the vessel, variations of draught of water, etc., will go far to offset each other, and will disappear in the final averages. The greater the amount of cruising the more accurate will these latter be."

In the back of the U. S. Naval Steam Log is a form with columns having the following headings: Date, Hours, Speed, Coal Expenditure (total per day, and for distilling and heating), Knots per Day and per Ton of Coal, Coal Endurance in Days and Knots, Months out of Dock, Direction and Force of Wind, Direction and Kind of Sea, Sail Carried, Kind and Quantity of Coal, Average Revolutions per Minute, Average Boiler Pressure and Average I.H.P. The data derived from a continuous run of seventy-two hours duration or more must appear in a single horizontal line of this form. Coal used for priming furnaces, warming up engines, boilers and piping does not appear in the record, only the coal consumption for steaming in free route.

The data contained in the log books being gathered together for each ship, a curve is constructed as described by Commodore Isherwood, the abscissae representing knots per hour, and the ordinates, tons of coal per day for all purposes. This work has

been done under the direction of the Engineer-in-Chief, by the late Lieut. C. A. E. King, U. S. N.; Lieut. B. C. Bryan, U. S. N., Lieut. C. W. Dyson, U. S. N. and Lieut. G. S. Lincoln, U. S. N. To Lieut. Dyson is due the construction of the coal speed curves.

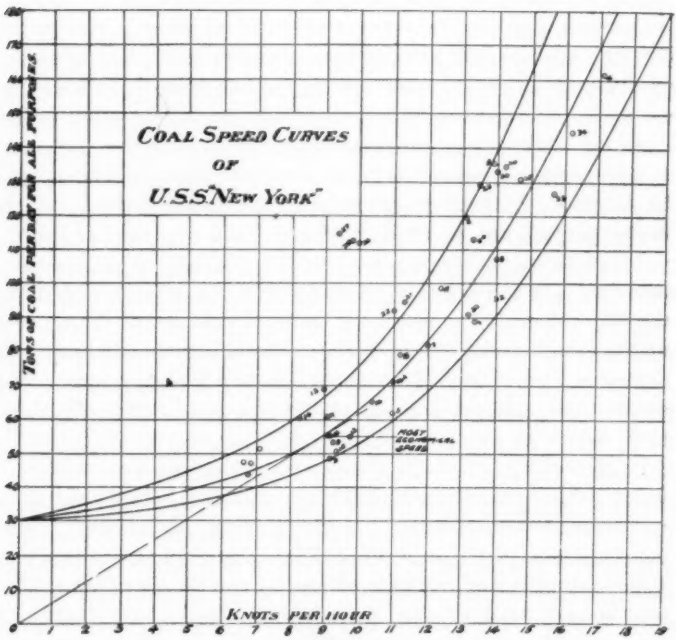



FIG. 1.

THREE CURVES ADVANTAGEOUS.

A glance at the plotted points shows how variable is the coal consumption for a given speed, sometimes without apparent reason. Still, the abnormal points are few, the others falling within well-defined limits, which can be drawn in as shown in Fig. 1, which is the curve of the U. S. S. *New York*. The lower curve shows what she can do when conditions are favorable, the upper one her performance under unfavorable conditions. The

middle curve shows her average performance. The most economical speed is shown by a line from the origin tangent to the curve. At most economical speed $\frac{y}{x}$, or $\frac{\text{coal}}{\text{speed}}$, should be a minimum. The condition for the tangent from the origin is $\frac{dy}{dx} = \frac{y}{x}$. If $\frac{dy}{dx} > \frac{y}{x}$, then $\frac{y' - dy}{x' - dx}$ is less than $\frac{y}{x}$ and the speed should be decreased. If $\frac{dy}{dx} < \frac{y}{x}$, then $\frac{dy + y}{dx + x} < \frac{y}{x}$ and the speed should be increased.

### FEW POINTS AT LOW SPEEDS.

While enough points can generally be obtained at from six to twelve knots, at higher or lower speeds, however, the points are too few. Not many of our ships have made continuous runs of long duration at high speed, and runs at very low speeds are equally rare, except in the case of small ships, and these generally had to run slow on account of the weather. Thus, it is difficult to determine the form of the curve below six knots, but from the few slow runs made by ships of the first class, it would seem that the coal expenditure under way never can fall much below about twenty-five tons per day for ships of this class

### COMPARISON OF COAL CONSUMPTION OF BATTLESHIPS.

In comparing the economies of different ships it was suggested to find the coal consumption at each speed for 1,000 tons displacement, reducing the coal consumption taken from the average curve of each vessel in the ratio of $\frac{(1{,}000)^{\frac{2}{3}}}{D^{\frac{2}{3}}}$, $D$ being the displacement taken from the Annual Report of the Bureau of Steam Engineering. The results of this reduction for battleships are given in Table I, for speeds of from four to twelve knots, the points on either side of these speeds not being sufficiently numerous to give a good determination of the average curve, nor is the reduction necessary. When a battleship starts cruising at a higher speed than twelve knots, nobody cares much about coal consumption or coal economy.

**TABLE I.**

| | Knots per hour. | | | | |
|---|---|---|---|---|---|
| | 4 | 6 | 8 | 10 | 12 |
| *Indiana* and *Massachusetts.* | | | | | |
| $D = 10{,}288$ | | | | | |
| $D^{\frac{2}{3}} = 473$ $C =$ | 38 | 45 | 59 | 78 | 104 |
| $\frac{100}{D^{\frac{2}{3}}} = .21$ $C_a =$ | 7.96 | 9.45 | 12.39 | 16.38 | 21.84 |
| *Iowa.* | | | | | |
| $D = 11{,}340$ | | | | | |
| $D^{\frac{2}{3}} = 504$ $C =$ | 46.8 | 56 | 72 | 94 | 120 |
| $\frac{100}{D^{\frac{2}{3}}} = .198$ $C_a =$ | 9.26 | 11.1 | 14.25 | 18.6 | 23.75 |
| *Oregon.* | | | | | |
| $D = 10{,}288$ | | | | | |
| $D^{\frac{2}{3}} = 473$ $C =$ | 34 | 42 | 52 | 68 | 89 |
| $\frac{100}{D^{\frac{2}{3}}} = .21$ $C_a =$ | 7.14 | 8.82 | 10.92 | 14.3 | 18.7 |
| *Wisconsin* and class. | | | | | |
| $D = 11{,}525$ | | | | | |
| $D^{\frac{2}{3}} = 509.5$ $C =$ | 36 | 46 | 58 | 72 | 92 |
| $\frac{100}{D^{\frac{2}{3}}} = .196$ $C_a =$ | 7.18 | 9.1 | 11.4 | 14.11 | 18.2 |
| *Kearsarge* and *Kentucky.* | | | | | |
| $D = 11{,}525$ | | | | | |
| $D^{\frac{2}{3}} = 509.5$ $C =$ | 36 | 43 | 54 | 71 | 90 |
| $\frac{100}{D^{\frac{2}{3}}} = .196$ $C_a =$ | 7.13 | 8.43 | 10.6 | 13.9 | 17.6 |

$D$ = displacement of the ship.
$C$ = actual average coal consumption per day at given speed.
$C_a = \frac{100}{D^{\frac{2}{3}}} \times C.$

COAL CONSUMPTION SEEMS TO FOLLOW A GENERAL LAW.

The similarity of the results is striking, the only ship differing much from the others being the *Iowa.* It is hard to find the reasons for her high coal consumption; perhaps there are many. The values of Table I are plotted as curves in Fig. 2, the ordinates and abscissae representing the same quantities as in Fig. 1. An analysis of these curves by Mr. A. H. Raynal showed that

they coincide very closely with a curve of the form $y = c + kx^2$. This being so, the coal-speed curves from which they were derived necessarily would be of the same form. A careful examination of these curves showed that the average coal speed curve of each battleship followed this form very closely up to ten or twelve knots. The equations for this curve in the case of each battleship are given below (Table II), and the deviation of the coal consumption given by these equations from that obtained from the curve as drawn for each ship (Table III).

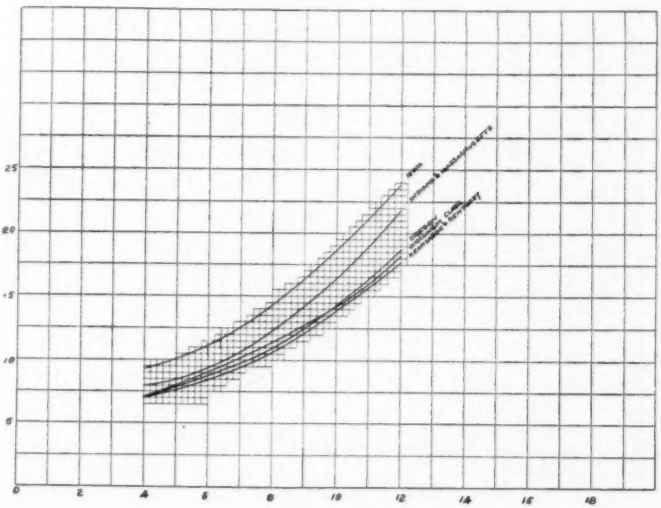


FIG. 2.

**TABLE II.**

EQUATIONS GIVING AVERAGE COAL CONSUMPTION AT DIFFERENT SPEEDS.

| | |
|---|---|
| *Indiana* and *Massachusetts* | $y = 28 + .50s^2$. |
| *Iowa* | $y = 38 + .55s^2$. |
| *Oregon* | $y = 24 + .45s^2$. |
| *Wisconsin* | $y = 28 + .45s^2$. |
| *Kearsarge* and *Kentucky* | $y = 30 + .40s^2$. |

$y$ = tons of coal per day for all purposes.
$s$ = speed in knots per hour.

**TABLE III.**

| Knots per hour. | Coal consumed. | *Massachusetts* and *Indiana*. | *Iowa*. | *Oregon*. | *Wisconsin* and class. | *Kearsarge* and *Kentucky*. |
|---|---|---|---|---|---|---|
| 4 | A | 36 | ... | 34 | 36 | 36 |
| | B | 36 | 46 | 32.2 | 34.2 | 36.4 |
| | C | ... | ... | −1.8 | −1.8 | +0.4 |
| | D | ... | ... | 5.2 | 5 | 1.1 |
| 6 | A | 46 | 56 | 42 | 46 | 43 |
| | B | 46 | 57.8 | 41.2 | 43.2 | 44.4 |
| | C | ... | +1.8 | +0.8 | −2.8 | +1.4 |
| | D | ... | 3.2 | 1.9 | 6 | 3.2 |
| 8 | A | 59 | 72 | 52 | 58 | 54 |
| | B | 60 | 73.2 | 53.8 | 56.8 | 55.6 |
| | C | +1 | +1.2 | +1.8 | −1.2 | +1.6 |
| | D | 1.7 | 1.6 | 3.4 | 2 | 3 |
| 10 | A | 78 | 94 | 68 | 72 | 71 |
| | B | 78 | 93 | 70 | 73 | 70 |
| | C | ... | −1 | +2 | +1 | −1 |
| | D | ... | 1 | 3 | 1.4 | 1.4 |
| 12 | A | 104 | 120 | 89 | 92 | 90 |
| | B | 100 | 117.2 | 89.8 | 91.8 | 87.6 |
| | C | −4 | −2.8 | +0.8 | −0.2 | −2.6 |
| | D | 3.8 | 2.3 | .9 | ... | 2.9 |

A = tons per day taken from curves as drawn by inspection.
B = tons per day given by equation (Table I).
C = A − B.
D = C ÷ A, expressed as a per cent.

The equations for the average curve for several other ships are given in Table IV. It will be noticed that the *New York's* equation gives twenty-eight tons at zero speed, while the curve as drawn gives thirty tons. The curve was drawn in before the equation was obtained, and the equation, very likely, is the more correct. It is seen that the right-hand number of the equation consists of a constant term and a variable term. The constant term represents the coal consumption at zero speed. This statement is a little vague, but considering the coal consumption *at one knot, as given by the equation*, we may get a clearer idea of

zero speed, which means under way, with steam on the main engines and the engines slowly turning over, but the ship making no way through the water. The coal consumption at one knot is little more than at zero speed. This is borne out in practice.

**TABLE IV.**

EQUATIONS GIVING AVERAGE COAL CONSUMPTION AT DIFFERENT SPEEDS.

*New York*..... $y = 28 + .38s^2$.
*Dixie*..... $y = 10 + .30s^2$.
*Detroit* and class..... $y = 9 + .23s^2$.
*Albany* and *New Orleans*..... $y = 15 + .26s^2$.
*San Francisco*..... $y = 13 + .25s^2$.
*Olympia*..... $y = 21 + .36s^2$.
*Bennington* and class..... $y = 7 + .18s^2$.

$y$ = tons of coal per day for all purposes.
$s$ = speed in knots per hour.

**TABLE V.**

| Knots per hour. | Coal consumed. | *New York.* | *Dixie.* | *Albany* and *New Orleans.* | *Detroit* and class. | *San Francisco.* | *Olympia.* | *Bennington* and class. |
|---|---|---|---|---|---|---|---|---|
| 4 | A | 36 | 14 | ... | ... | ... | ... | 10.5 |
| | B | 34.08 | 14.8 | 19.16 | 12.68 | 17 | 26.76 | 9.88 |
| | C | —1.92 | +0.8 | ... | ... | ... | ... | —0.62 |
| | D | 5.3 | 5.7 | ... | ... | ... | ... | 6 |
| 6 | A | 42 | 20 | 27* | 17 | 22 | 35 | 13.75 |
| | B | 41.68 | 20.8 | 27.79* | 17.28 | 22 | 33.9 | 13.48 |
| | C | —0.32 | +0.8 | +0.79* | +0.28 | ... | —1.1 | —0.27 |
| | D | .76 | 4 | 2.9* | 1.6 | ... | 3.1 | 2 |
| 8 | A | 50 | 28 | 30 | 23 | 28 | 45 | 18.25 |
| | B | 52.32 | 29.2 | 31.64 | 23.72 | 29 | 44.04 | 18.52 |
| | C | +2.32 | +1.2 | +1.64 | +0.72 | +1 | —0.96 | +0.27 |
| | D | 4.6 | 4.3 | 5.4 | 3.1 | 3.6 | 2.1 | 1.4 |
| 10 | A | 63 | 40 | 39.5 | 31 | 38 | 57 | 25 |
| | B | 66 | 40 | 41 | 32 | 38 | 57 | 24.25 |
| | C | +3 | ... | +1.5 | +1 | ... | ... | —0.75 |
| | D | 4.8 | ... | 3.8 | 3.2 | ... | ... | 3 |
| 12 | A | 83 | 54 | 53 | 45 | 51 | 74 | 30.5 |
| | B | 82.72 | 53.2 | 52.44 | 42.12 | 49 | 72.84 | 29.92 |
| | C | —0.28 | —0.8 | —0.56 | —2.9 | —2 | —1.16 | —0.58 |
| | D | 0.3 | 1.5 | 1 | 6.4 | 3.9 | 1.6 | 1.9 |

*At 7 knots.

It is interesting to notice the close agreement between the constants in the equations for the *Iowa* and *Massachusetts* with the average daily coal consumption of those ships while blockading off Santiago de Cuba in 1898, as computed by Lieutenant C. W. Dyson (Record of Proceedings of a Court of Inquiry, etc.). He gives 38.96 tons per day for the *Iowa* and 30.8 tons for the *Massachusetts*, the constants being 38 and 28. An examination of the log of the *Oregon* while blockading off Santiago shows that day after day she burned from twenty-one to twenty-six tons on this duty; the constant in the equation is twenty-four. The conditions of the blockade off Santiago de Cuba very nearly fulfilled the conditions for zero speed given above, and the coal consumed on this blockade agrees very closely with the amount given by the equation.

Figure 3 gives the average coal-speed curve for the U. S. S. *Dixie*, which coincides very closely with the curve given by

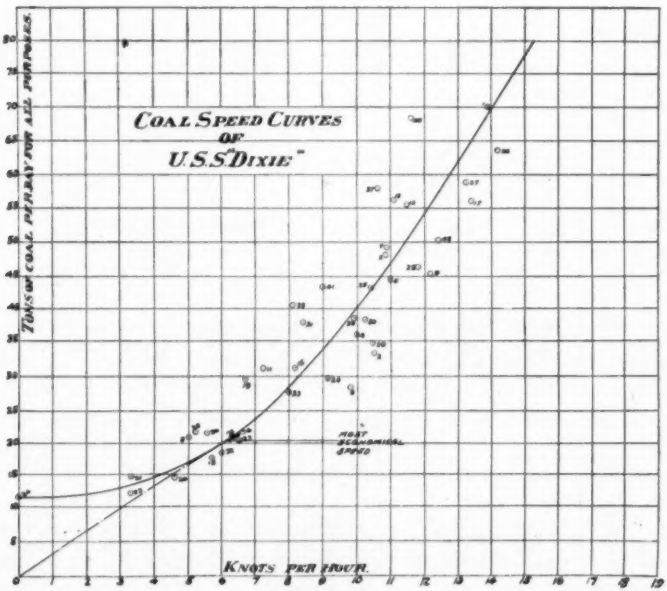



FIG. 3.

$y = 10 + .3x^2$, the greatest deviation being 1.2 tons at 8 knots. One point is shown at zero speed, this point representing the coal burned while drifting at sea, keeping the engines warmed up and turning them over every little while. The amount thus burned tallies closely with the amount given by the equation.

The other term of the right-hand member, $cs^2$, is the product of two variables, $c$, varying with condition of bottom, weather, efficiency of screw, etc., but constant for a given condition, and $s$, the speed of the ship. From the close coincidence of the curves given by this equation with the avearage coal-speed curves plotted from many runs of the various ships, may we not fairly conclude that the average coal consumption of our ships, as now built, is expressed by an equation of the form $y = k + cx^2$?

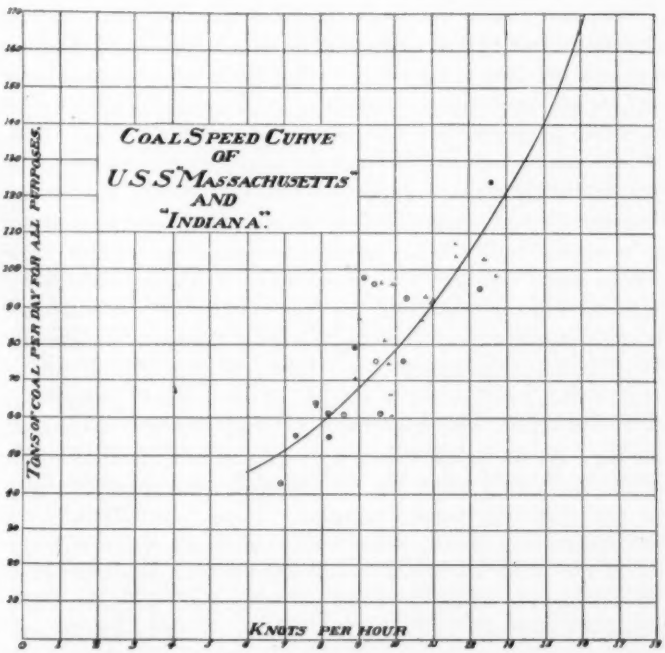



FIG. 4.

MOST ECONOMICAL COAL CONSUMPTION.

If the coal consumption of our ships follows the law $y = k + cx^2$ up to about twelve knots, the following conclusions are a consequence:

It has been noticed that the condition for the tangent from the origin is $\frac{dy}{dx} = \frac{y}{x}$. From the equation, $y = k + cx^2$, $dy = 2cxdx$,

$$\frac{dy}{dx} = 2cx = \frac{y}{x},$$

$$2cx^2 = y = k + cx^2,$$

$$cx^2 = k.$$

That is: *At the most economical speed the coal consumption is twice that at zero speed.*

From this comes the conclusion that each ship has a certain economical rate of coal consumption, which is twice the amount necessary to just get under way. This latter amount includes the coal for all auxiliary purposes, that is, the coal consumed for any other purposes than for *power delivered to the screw.* This amount can be kept nearly constant in any ship. As shown by Prof. Hollis (JOURNAL AMERICAN SOCIETY OF NAVAL ENGINEERS, Volumes IV and V), the coal for auxiliaries is nearly constant up to eleven knots, and the other factors entering into this "coal at zero speed" are not greatly variable. If the auxiliaries are kept in good condition, and the boilers clean; if the coal used stays about the same qualtity and the firing the same, this amount should be nearly constant. Then if the coal consumption follows the equation $y = k + cx^2$, this "coal at zero speed" governs the most economical coal consumption, which is nearly a constant amount. As the coefficient $c$, depending on the condition of the bottom of the ship, wind, sea, etc., changes, $s$, the speed, changes, but their product remains constant. Instead of seeking for a most economical speed, which is different every run, it is better to find the most economical coal consumption, the amount of coal per day for which the knots per ton are a maximum, under ordinary conditions of running, which is far more nearly constant than the "most economical speed." Then when burning

this amount of coal, the ship is very likely making the greatest of knots per ton of coal possible, and her cruising radius will be a maximum.

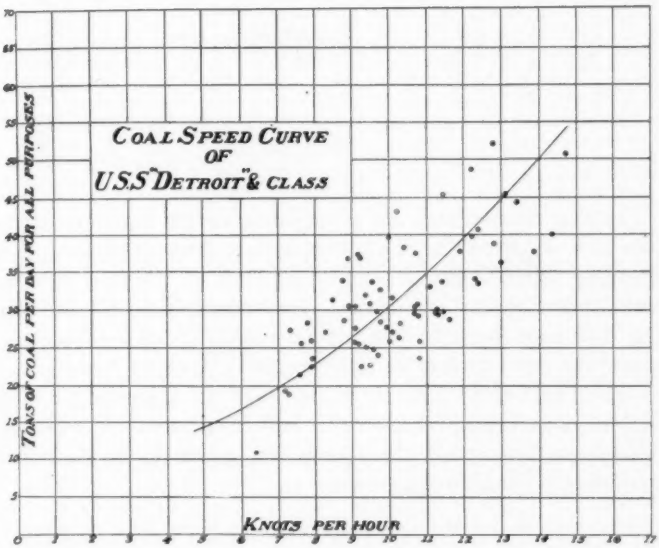



FIG. 5.

On page 70, Volume V, of the JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS, Professor Hollis gives a table showing, among other things, the estimated total coal per hour in pounds for the U. S. S. *Charleston*. In line I of Table VI below, these amounts are given in tons. Line II of the same Table shows the amounts given by the equation $y = 14 + .25s^2$, the differences being given in line III. Up to ten knots the difference is not large.

Professor Hollis' table gives the coal for the various auxiliaries in use and for the main engine separately. At 4 knots the total given for auxiliaries is 1,229 pounds per hour, and 428 pounds per hour for the main engines. At zero speed the main engines would use perhaps one-third of this latter amount, giving 1,371

pounds per hour total coal consumption, or 14.66 tons per day, which is not far from the constant 14 in the equation.

TABLE VI.

| | Knots per hour. | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 2 | 4 | 6 | 8 | 10 |
| I | ... | ... | 17.75 | 22.76 | 29.22 | 41.13 |
| II | ... | 15 | 18 | 23 | 30 | 39 |
| III | ... | ... | +.25 | +.24 | +.78 | −2.13 |

The coal consumption can be expressed by an equation of the form of $y = k + cx^3$, as the following equations will show. (See article by Chief Engineer John Lowe, U. S. N., JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS, Vol. III, p. 219. The difference between the amounts taken from the curve as drawn and the amounts as given by the equations $y = k + cx^3$ are given in Table VIII. It is seen that the agreement is fully as close as in Tables III and IV. Still, if the coal consumption follows any law at all, the square law seems to be the more accurate, for the following reasons:

TABLE VII.

| | |
|---|---|
| *Massachusetts* | $y = 37 + .040s^3$. |
| *Iowa* | $y = 48 + .045s^3$. |
| *Oregon* | $y = 34 + .032s^3$. |
| *Wisconsin* and class | $y = 41 + .030s^3$. |
| *Kearsarge* and *Kentucky* | $y = 39 + .030s^3$. |
| *New York* | $y = 33 + .030s^3$. |
| *Dixie* | $y = 14 + .025s^3$. |
| *Albany* and *New Orleans* | $y = 20 + .020s^3$. |
| *Detroit* and class | $y = 12.5 + .020s^3$. |
| *San Francisco* | $y = 18 + .020s^3$. |
| *Olympia* | $y = 32 + .025s^3$. |
| *Bennington* and class | $y = 10 + .012s^3$. |

We have shown that if $y = k + cx^2$, the most economical coal consumption is twice the coal consumption at zero speed. Likewise, if $y = k + cx^3$, the coal at zero speed is two-thirds of the most economical coal consumption. A glance at the *Dixie's*

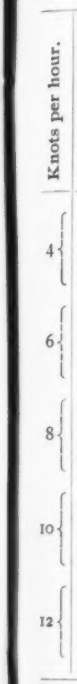


**TABLE VIII.**

| Knots per hour. | Coal consumed. | *Massachusetts* and *Indiana*. | *Iowa*. | *Oregon*. | *Wisconsin* and class. | *Kearsarge* and *Kentucky*. | *New York*. | *Dixie*. | *Albany* and *New Orleans*. | *Detroit* and class. | *San Francisco*. | *Olympia*. | *Bennington* and class. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | A | 36 | ... | 34 | 36 | 36 | 36 | 14 | ... | ... | ... | ... | 10.5 |
| | B | 39.56 | 50.88 | 36.04 | 42.92 | 40.92 | 34.92 | 15.6 | 21.28 | ... | 19.28 | 33.6 | 10.76 |
| | C | +3.56 | ... | +2.04 | +6.92 | +4.92 | −1.08 | +1.6 | ... | ... | ... | ... | +0.26 |
| | D | 9.9 | ... | 6 | 19.2 | 13.67 | 3 | 11.4 | ... | ... | ... | ... | 2.5 |
| 6 | A | 46 | 56 | 42 | 46 | 43 | 42 | 20 | 27 | 17 | 22 | 35 | 13.75 |
| | B | 45.64 | 57.72 | 40.91 | 47.48 | 45.48 | 39.48 | 19.4 | 24.32 | 16.82 | 22.32 | 37.4 | 12.59 |
| | C | −0.36 | +1.72 | −1.09 | +1.48 | +2.48 | −2.52 | −0.6 | −2.68 | −0.18 | +0.32 | +2.4 | −1.16 |
| | D | .78 | .3 | 2.6 | 3.2 | 5.7 | 6 | 3 | 9.9 | 1.1 | 1.4 | 7 | 8.4 |
| 8 | A | 59 | 72 | 52 | 58 | 54 | 50 | 28 | 30 | 23 | 28 | 45 | 18.25 |
| | B | 57.48 | 71.04 | 50.38 | 56.36 | 54.36 | 48.36 | 26.8 | 30.24 | 22.74 | 28.24 | 44.8 | 16.14 |
| | C | −1.52 | −0.96 | −1.62 | −1.64 | +0.36 | −1.64 | −1.2 | +0.24 | −0.26 | +0.24 | −0.2 | −2.11 |
| | D | 2.6 | 1.3 | 3.1 | 2.8 | .66 | 3.3 | 4.3 | .8 | 1.1 | .85 | .4 | 11.6 |
| 10 | A | 78 | 93 | 68 | 72 | 71 | 63 | 40 | 39.5 | 31 | 38 | 57 | 25 |
| | B | 77 | 93 | 66 | 71 | 69 | 63 | 39 | 40 | 32.5 | 38.6 | 57 | 22 |
| | C | −1 | ... | −2 | −1 | −2 | ... | −1 | +0.5 | +1.5 | ... | ... | +3 |
| | D | 1.2 | ... | 3 | 1.4 | 2.8 | ... | 2.5 | .12 | 4.84 | ... | ... | 12 |
| 12 | A | 104 | 120 | 89 | 92 | 90 | 83 | 53.2 | 53 | 45 | 51 | 74 | 30.5 |
| | B | 106.12 | 125.76 | 89.29 | 92.84 | 90.84 | 84.84 | 57.2 | 54.56 | 47.06 | 52.56 | 75.2 | 30.73 |
| | C | +2.12 | +5.76 | +0.29 | +0.84 | +0.84 | +1.84 | +4 | +1.56 | +2.06 | +1.56 | +1.2 | +0.23 |
| | D | 2 | 4.8 | .3 | .9 | .9 | 2.2 | 7.5 | 3 | 4.6 | 3 | 1.6 | .75 |

curve shows that on one occasion she has made 3.15 knots per hour on 12 tons per day, and on 14 tons at another time. On 14 tons she made one run at 4.6 knots speed. Her most economical coal consumption seems to be about 21 tons per day, one-half of which is 10½ tons per day, or very nearly the constant of the equation $y = 10 + cx^2$. Two-thirds of 22 tons is 14.66 tons, which seems too large for the coal at zero speed, for she has made 4.6 knots per hour on this amount.

The amounts burned on blockade by the *Massachusetts*, *Iowa* and *Oregon* have already been given, and they seem to be about one-half the most economical coal consumption of these ships. Two-thirds of the most economical coal consumption is much

larger than the amounts used on the blockade, where the engines made from 9,000 to 15,000 turns per day.

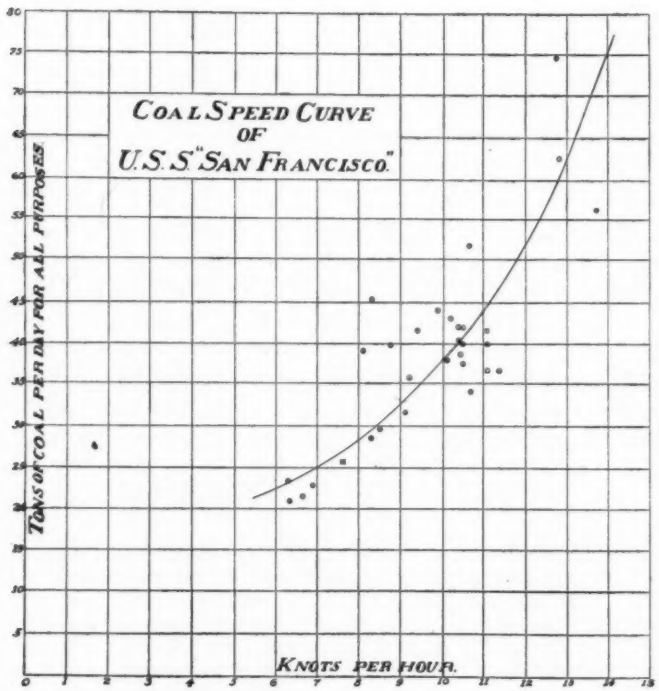



FIG. 6.

As to the use of the foregoing: The coal-consumption curve of a ship may be obtained as follows: A *few* days' trial with, say one-third of the boilers and all the usual auxiliaries in use will give a fair idea of the coal at zero speed. This trial can be run alongside the dock. The main engines must not be run too fast. Then there should be a run of a few days burning twice this coal at zero speed, to determine the most economical speed under the given conditions. Thus we may obtain two points of the coal-consumption curve, and determine the curve up to twelve knots.

This will be only one curve of an infinite number. We have stated that $k$ can be kept nearly constant, but $c$ is a variable, and we can have any number of curves starting at the same point at zero speed and diverging as the speed rises. But if a curve is determined as described above, we can consider the conditions of weather, sea, bottom, coal, etc., and form a pretty correct opinion as to whether it represents a performance under favorable, unfavorable, or average conditions, and limiting curves drawn in accordingly. Closer than this we cannot come.

Of course, the foregoing takes no account of the effect of a current on the most economical speed and coal consumption. A current alters both the most economical coal consumption and the most economical speed for the time being. The ship may be making her way through the water most economically, but not over the ground. For the benefit of any who may not remember how the effect of a current is allowed for, the following method, which is the same as that given in Engine-Room Practice, by John G. Liversidge, R. N., is inserted.

If the current is adverse, lay off on the horizontal axis to the right of the origin, a distance to represent the speed of the current. From the point thus obtained the tangent drawn to the curve shows the most economical speed for the time being. If the current is favorable, the distance should be set off to the left of the origin.

# REVISION OF THE BOILER LAWS OF THE U. S. STEAMBOAT INSPECTION SERVICE.

By Colonel E. D. Meier, Associate.

## INITIAL STEPS.

A revision of these laws has been urged by the Committee on "Uniform Boiler Specifications" of the American Boiler Manufacturers' Association. After careful investigation and discussion of the whole subject by this committee, they met the Board of Supervising Inspectors of Steam Vessels by invitation on January 28, 1903, and presented the matter fully to the Board. Thereupon Mr. Robert S. Rodie, Supervising Inspector of the Second District, offered the following resolution:

"Whereas, a committee of the American Boiler Manufacturers' Association has laid before this Board a comprehensive plan for an entire revision of the present boiler law of this inspection service, as per copy of letter to Senator Frye attached hereto, which is to be undertaken by an expert commission representing all interests involved:

"Be it resolved that the Board recognizes the force and fairness of this proposal, and trusts that such action may be taken, and pledges its hearty assistance and co-operation."

This resolution was unanimously passed.

The committee then called in a body on the Secretary of the Treasury and on the chairmen of the proper committees in the Senate and House, finding everywhere favorable consideration. The shortness of the session and the fact that the time was so fully occupied with the Panama canal and the Cuban reciprocity bills prevented any action at this time, although the Senate Bill (S. 7243) presented by Senator Frye, was twice read and referred to the Committee on Commerce, who reported it without amendment. The necessity and wisdom of the course proposed being thus generally acknowledged, the committee will bring up the

matter in the next session of Congress, where it is hoped speedy and favorable action will be obtained.

There are so many interests involved in this measure that a short history of the work and discussions which led up to it seems pertinent. The importance of the control intrusted to the Steamboat Inspection Service also demands a short statement of what has been accomplished, in order to better explain the necessity of revision.

### THE LEADERS IN THIS MOVEMENT.

There is sound reason why the A. B. M. A. should lead in this matter. This Association was founded in 1889, for the express purpose of improving the boiler business of the United States by establishing the highest standards for workmanship and material. The first work of the Association was the adoption of standard materials, which have since become known to the trade by the initials of the Association, "A. B. M. A." The next step was the appointment of a Committee on Uniform Boiler Inspection Laws, and successive committees did yeoman service in various States, in 1890, '91, '92, '95 and '96. In each case, after most strenuous work generally with the intelligent assistance of various societies of steam engineers, the result was failure. The reasons were always the same. The legislators concluded that any inspection law would work hardship to the manufacturers and purchasers of the many portable boilers which are used for farm machinery, for oil wells, etc. It was the usual experience which every reform and improvement meets, those needing the inspection most opposed it most violently.

The writer found at that time that from 1886 to 1896, inclusive, there were reported only 157 explosions of boilers in cities and towns against 1,985 in the country districts, although the total steam power in the former, where large manufacturing establishments are located, greatly exceeds that of farms, saw mills, etc.

But this continued experience forced upon the Association the recognition of the fact that the public conscience was not educated up to the necessity for intelligent inspection and control, and an

educational campaign was decided on as the only recourse. The Committee on Materials and Tests had been acting in this line from the beginning, and was able to report increasing success, inasmuch as engineers all over the United States and in many foreign countries fully accepted the A. B. M. A. standards.

At the Philadelphia convention of 1897 the writer suggested the appointment of a committee to draw up uniform specifications for American boilers, based on the experience of the membership as laid down in reports and topical discussions extending over a period of eight years. This committee held several meetings during that and the following year, and on October 3, 1898, presented its final report to the convention assembled at St. Louis, Mo. After a very full and active discussion, resulting in some minor amendments, this report was unanimously adopted by the convention on October 4.

Meanwhile there had been frequent complaints as to the embarrassments created in marine boiler work by the antiquated laws and arbitrary rulings of the Steamboat Inspection Service. As far back as 1892 Senator Frye introduced a bill which was intended to correct these evils. Unfortunately, the technical work on this bill was done in private and without any consultation with or any discussion by the great interests it effected, *i. e.*, plate manufacturers, boiler builders and ship owners. While the work as a whole reflected great credit on the engineers who selected the rules, there were many practical difficulties and present necessities which it did not reach at all. At a meeting of the marine engineers and boiler builders of New York City and neighborhood the statement was made that it seemed to be formulated and its provisions copied after rules of the Board of Trade of Great Britain. On examination it was found that its specifications for material were less precise and exacting than those of the A. B. M. A.; no chemical tests were prescribed for the materials, and good local practice was entirely ignored. This bill was fully discussed by the A. B. M. A., with representatives from the Atlantic seaboard shipping interests and from the U. S. Inspection Service at a meeting in Buffalo, and its developed that the bill paid no regard to the well established

defeat was urged by these three bodies. In this discussion it boiler practice of Western rivers and lakes and that some of the rules proposed would tie up, until they could be repealed, a large proportion of the interior and coastwise shipping of the country. In the discussion all expressed the most heartfelt regret that these matters of detail should make it necessary to oppose and defeat a measure, the inception and spirit of which they warmly applauded, and entertained the hope that at some future time the very bodies then opposing it might obtain the benefit of the wise counsel and strong influence of Senator Frye in introducing and passing a comprehensive bill, embodying the experience and knowledge of all concerned. Several meetings of individual members of the A. B. M. A. with the Board of Supervising Inspectors at Washington did indeed result in occasional modifications of rules which worked hardship. But the conviction grew that a complete revision of the law had become a necessity.

On August 13, 1901, at the thirteenth annual convention, Mr. Rees, of Pittsburg, brought in a protest against several onerous rules, and on motion the whole matter was referred to the Committee on Uniform Boiler Specifications, which was increased to nine members by adding several men specially versed in marine boiler building. This committee met in New York November 12, 1901, and with the Board of Supervising Inspectors in Washington January 21, 1902. In this meeting the limit of the power of the Board to meet the requirements of modern practice was clearly defined, and while some corrections of previous rulings were granted, it became clear that the committee could only hope for success by urging the entire revision of the law itself. A full canvass of the membership during 1902 showed a very general appreciation of the necessity of this movement and willingness to co-operate in it. After the necessary preparatory work had been done, at a meeting held December 18, 1902, in New York, the action before indicated was taken.

### THE INSPECTION SERVICE.

Steamboat inspection service dates its beginning from the Act of 1852, which simply prescribed that all makers of *iron* boiler

plate must stamp each plate with their names, place of manufacture and a letter to indicate whether charcoal or puddled *iron* was used in making the plate; there being no penalty the reputation of the maker was the only safeguard to the purchaser. In 1872 another law was passed, according to which the stamp must give the name of the maker, place of manufacture and the tensile strength, and a penalty of $2,000 and two years' imprisonment was provided to guard against fraudulent stamping. In 1877 Jas. A. Dumont was appointed Supervising Inspector General, and took further action under the law. First, he placed testing machines in the ten districts, and on November 22, 1877, directed inspectors to subject all plates of boiler *iron* to actual test before the boilers are begun, and carefully ascertain the homogeneousness and toughness of material "where plates are stamped over 50,000 pounds tensile strength."

At his request, in January, 1878, the principal boiler-plate manufacturers of the United States met and advised with the Board of Supervising Inspectors on matters pertaining to testing, etc., and the conclusions were embodied in the rules.

Naturally a marked improvement in the materials and workmanship resulted from this closer inspection, and in 1882 Mr. Chas. Huston, the veteran plate maker (in whose mill the first boiler plate ever made in the United States was rolled in 1810), wrote to the Secretary of the Treasury that "the present rules and regulations are probably the best that are to be found in any nation." That Mr. Huston had good reasons for this opinion is shown by the statistics of the service.

From 1858 to 1860 there are recorded 721 deaths by accident on 1,687 steamers. This was at the rate of one life lost per annum for 2.34 steamers, or for 138,700 passengers. In the decade from 1868 to 1878 we have 365 deaths on 3,645 boats, being one life per annum for every 10 steamers, and for 821,600 passengers. In the next decade, ending with 1888, we have 213 deaths on 5,344 boats, or one life for every 25 steamers, and for 2,347,400 passengers. This shows that by intelligent inspection travel on boats was six times safer in the second and seventeen times safer in the third decade than it had been in the first.

In the year 1901, 13,551 boilers on 9,253 vessels were inspected by the service, and they reported 150 passengers lost out of a total of 306,353,522, making one passenger lost for every 61.7 steamers, or one out of every 2,042,357. But as we are concerned with boilers only in this discussion, we find that there was only one passenger killed out of 13,925,160 by steam escaping through explosion or rupture of any kind whatsoever. Only eleven boilers caused damage, either by explosion or by partial rupture of parts of the boilers or connecting pipes, *i. e.*, only one out of 1,232 boilers caused serious trouble.

For the whole United States there are reported during 1901, 423 explosions or ruptures; of these 89½ per cent. were due to land boilers, 9.2 per cent. to locomotive boilers, and only 1.3 per cent. to boilers used on boats. These few figures show the immense value of an intelligent and conscientious inspection service. It must be remembered that this service was rendered under laws and rules which have become antiquated and ill adapted to the new conditions created by the great improvements in materials for boiler work, and in methods, machinery and manufacture, as well as by a radical change in marine service, notably higher pressures of steam and the necessity for higher furnace temperatures and more rapid and economical evaporation.

## NECESSITY OF REVISION.

The question may be asked: If the inspection service shows such good results under the old laws, why is a change demanded? One little set of figures by way of illustration: In 1901 there were 1,525 *iron* boilers, 1,352 coil and pipe boilers and 10,674 steel boilers inspected. But as we have seen, the laws and rules under which these inspections must be held were built up originally on the conditions which existed in 1877, when the leading plate manufacturers of the United States met together to discuss the qualities of boiler *iron*. The figures just quoted show that there are seven times as many steel boilers in use now as iron boilers, and nearly as many coil and pipe boilers as the latter. These changes in materials and construction and in fundamental design cannot be intelligently and honestly met by rulings based on

laws passed when neither steel plate nor pipe boilers were thought of. A critical examination of the rules shows many inconsistencies and contradictions, and there are some matters in which the long established practice and ruling of the Board has resulted in evasion, if not in violation, of the meaning of the law. Section No. 4,433 says in plain language that the working pressure shall not produce a strain to exceed one-sixth of the tensile strength of the material for single-riveted, nor one-fifth of the tensile strength for double-riveted seams. Until two years ago no rules for proportioning rivet seams were ever promulgated. But in practice the above provision of the law was construed as though it applied to the full metal, the seam value being ignored. The formulas for joints, taken from the British Board of Trade, tabulated by Traill, were adopted by the Board in January, 1901. Applying these new rules to the table of pressures published by the Board, gives us factors of safety in the net metal of only 3.5 in $\frac{3}{8}$-inch steel and 3.29 in $\frac{7}{16}$-inch steel. In the absence of any provision of the law the Board has no power to give builders the benefit of the greater seam values attained in the triple-riveted lap or double butt-strapped joints. The law knows nothing beyond the double-riveted lap.

When the service was first established Congress evidently had in mind steamboats, and the problems presented by the great steamships of the Atlantic and Pacific, as well as those on our great lakes, were not then so prominent. By building boilers of small diameter, generally 42 inches and 44 inches for the high-pressure boats on the great western rivers, and of larger diameter for the low-pressures in use on the eastern lake, river and coastwise steamers, these specific provisions, all made for thin plates, could be applied with but slight modification. But, since pressures have risen to 200 pounds and over for triple and quadruple-expansion engines, and since the advent of the internally-fired Scotch boiler, of pipe boilers and of steel plate running up to and above 70,000 pounds tensile strength, this is no longer possible. The best modern practice on land, and that of the Navy Department on salt water, meet these differences because untrammeled by antiquated rules. To enable the Steamboat In-

spection Service to do this, radical changes in the law are necessary. The under-fired Mississippi river boiler must be made of ductile and very thin plates to stand the fierce fire on one side and the ever-present mud on the other. In the Scotch marine boiler the outer shell untouched by fire presents simply a static problem, and must be constructed of plates of high tensile strength. Steel manufacturers are now prepared to meet every condition presented by boiler problems; but the chemical composition of those various alloys of iron which we have agreed to call steel must vary according to different demands for tensile strength, ductility, etc.

Another feature of the practice of the service requires amendment. Rules may be changed each year only during the January meeting of the Board of Supervising Inspectors. These officials, when not chosen simply for political reasons, have been promoted either from the inspectors of hulls or the inspectors of boilers. It thus frequently happens that important matters connected with steam boilers and machinery have to be passed on by a Board on which, perhaps, only three or four members are specially posted on them. The matters presented often come up suddenly, leaving no time for members of the Board to make special preparatory study. They would be more than human did they not frequently fall into grave error, and, of course, only the party specially interested in the change will be heard, as others, whose interests may be as great, though different, cannot be notified in time to be present. Thus, some twenty years ago a certain theory was advanced in regard to inequalities of pressure which led to legislation demanding that steam-drum legs must have one square inch of area for every two square feet of "effective" heating surface. What "effective" heating surface means would be a problem for lawyers, as there is no definition extant in engineering practice. Of course, to base such area on heating surface at all is faulty; for we have different types of marine boilers in this country, some whose hourly work is the evaporation of three pounds and others that of twenty pounds per square foot of heating surface—the latter, of course, very "effective."

The grate area, draft and kind of coal used are, of course, the true determining factors for the size of steam openings. As far back as 1886 the hardship of this particular law was made so manifest to the Board that they recommended a change to one square inch opening for every four square feet of heating surface; but there the matter dropped, and the old rule remains.

There is another rule which works great hardship, viz: that "Materials for repairs must be tested in the district where used." Following is a case illustrating the hardship of this rule: A boiler originally built in Pittsburg was to be repaired in a Southern coast city. Material of exactly the required quality could be obtained in Pittsburg and verified by the local inspector there, and the plate prepared according to the blue prints of the original builder. But the rule prevented this, and the boat was tied up for a long time in consequence. There is no sound reason why boiler steel tested at the mill where manufactured and properly inspected and stamped by a U. S. inspector should not be used in any port or river town of the United States. The practice of the Navy in this matter presents a good and sufficient precedent.

Several peculiar cases have come up under the provision of Section No. 4,433, that other parts of boilers shall correspond in strength to the allowances made for the shell. For instance, a boiler manufacturer arranges the braces for his boiler for the required steam pressure, say 100 pounds. But in order to increase the life of the shell and to provide against deterioration by pitting and rusting he makes the shell one-sixteenth inch or more thicker than the law requires. A ruling is at once applied that now he must increase the strength of his bracing so that it will correspond to the pressure which by the rules the thicker shell may be allowed to carry. Here is adherence to the "letter that killeth" with a vengeance, and it frequently works great hardship.

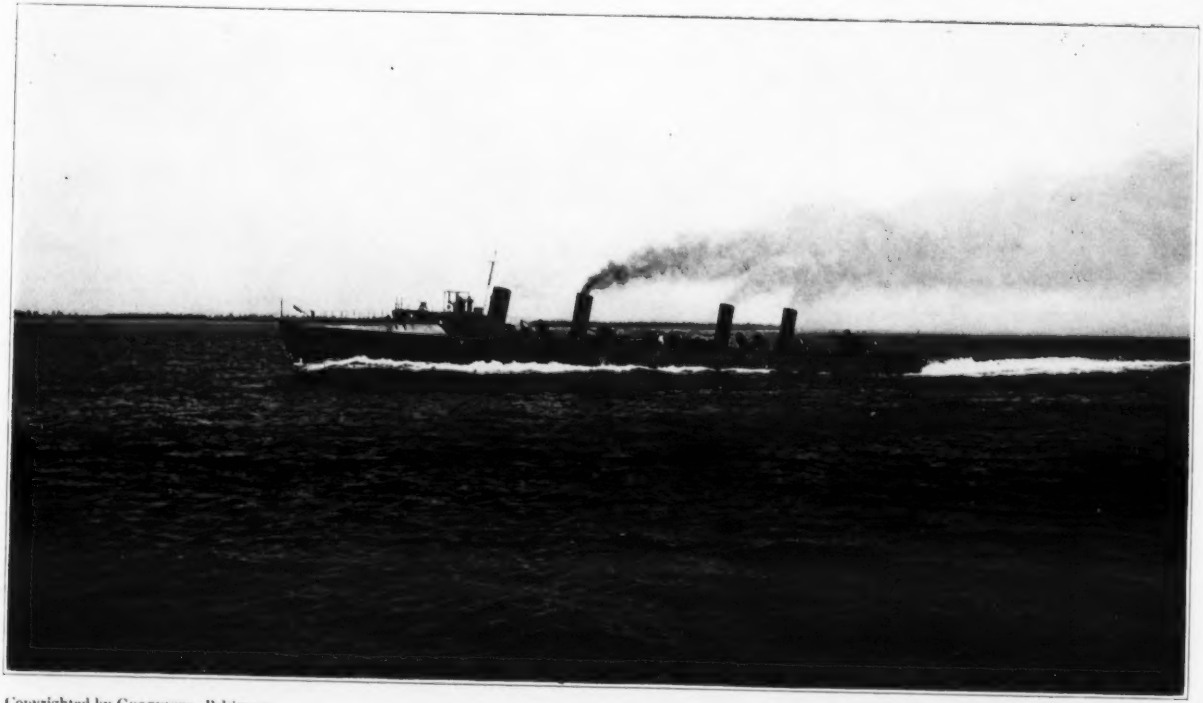
The necessity of some rational system of proportioning rivet seams has been so fully impressed on the Board that the adoption of Traill's rules seems to have been the result of the energy of despair. But they do not work out with modern American practice. The many tests made at Watertown have shown us that it is not safe to figure on more than 40,000 pounds rivet

shear, and further that where the rivet strength somewhat exceeds the tensile strength of the standing metal the latter shows from 4,000 to 5,000 pounds per square inch better than in the test piece. The rules as printed in the appendix fix arbitrarily the ratio of the area of the net plate to rivet section as .8214. The inevitable result is that in such a joint, steel plate of 56,000 pounds tensile strength requires 46,000 pounds rivet shear, and plate of 65,000 pounds tensile strength, a not at all unusual strength, requires 53,393 pounds of rivet shear. Apply this to "Table of pressures allowable on boilers built since February 28, 1872," and you find that the factor of safety in the net plate runs over the scale as follows: 3.5; 3.46; 3.37; 3.3; 3.29; and the factor of safety in the rivets, based on 40,000 pounds shearing strength, runs: 2.9; 2.6; 2.53; 2.49 and 2.47 on plate varying from $\frac{3}{8}$ inch to 1 inch in thickness. These few examples (and many more could be cited) show conclusively that the good results obtained by the Inspection Service are due to the conscientious work of its members and of the builders of boilers, and have been obtained not in consequenence of, but in spite of laws and rules under which they worked.

There are other points, showing the insufficiency of the law, which might be cited; rules which were sound when passed and are sound today for the limits then existing may tend to hardship and danger in the larger limits set by modern practice; for instance, safety valves of sufficient area for 50 pounds become dangerous by their very size at 200 pounds.

Finally, an entire rearrangement of the sections of the law is imperative to avoid trouble, and actual conflicts in statements must be eliminated. Questions of design should come first, next materials and their inspection; then test, factors of safety, methods of workmanship, and finally matters of location, connections and accessories. An entire revision at the hands of competent experts seems the only solution of the question; and this committee should consult all the main interests affected, viz: the Inspection Service, the Navy, Revenue Cutter Service, naval architects, marine engineers, boiler manufacturers, plate manufacturers and ship owners.

The requirements and necessities of each of these great interests harmonized in the full knowledge of conditions and problems, which a joint discussion by these experts would evolve, will give us a law and an inspection service commensurate with the vast interests of the foremost manufacturing people of the world, and one which will stimulate in place of repressing the development of that maritime superiority, the attainment of which has become a recognized necessity.



Copyrighted by GROENIGER, Baltimore

**FIG. 1.**—U. S. TORPEDO-BOAT DESTROYER "WORDEN" AT THIRTY KNOTS SPEED.

# U. S. TORPEDO-BOAT DESTROYERS *TRUXTUN, WHIPPLE* AND *WORDEN.*

By H. A. MAGOUN, ASSOCIATE,

SUPERINTENDING ENGINEER, MARYLAND STEEL CO.

In Vol. XIV, No. 4, of the JOURNAL a very complete account of the official speed trials of the U. S. torpedo-boat destroyers *Truxtun*, *Whipple* and *Worden* was published.

These destroyers, having all very successfully completed their final acceptance trials quite recently, it is considered timely to give a short description of certain features of the vessels, accompanied by general plans, only such data being repeated as will make the present matter complete.

The *Worden* is generally referred to, her trial data being the more complete.

GENERAL DATA—*WORDEN.*

| | |
|---|---|
| Length of hull over all, feet and inches | 259-6 |
| on trial-load line, feet and inches | 251-2 |
| Trial draught, maximum, feet and inches | 9-8½ |
| forward, to bottom keel, feet and inches | 6-8½ |
| aft, to bottom keel, feet and inches | 6-6½ |
| mean, to bottom keel, feet and inches | 6-7½ |
| Beam at deck, feet | 23 |
| L.W.L., feet and inches | 22-6 |
| Molded depth at side, amidships, feet and inches | 14-8 |
| center, amidships, feet and inches | 15-7 |
| Maximum trial displacement, tons | 492.6 |
| Mean trial displacement, tons | 480.2 |
| Tons per inch at L.W.L. | 9.8 |
| Area, midship section, square feet | 95.36 |
| Block coefficient | .48 |
| Metacenter above center of gravity, feet | 3.84 |
| Moment to alter trim one inch, foot tons | 111 |
| Wetted surface, square feet | 5,280 |
| I.H.P. at 28 knots | 7,100 |
| per square foot of grate | 22.54 |

| | |
|---|---|
| Air pressure at 28 knots | 4.5 |
| I.H.P. at 30 knots | 8,450 |
| per square foot of grate | 26.82 |
| Air pressure at 30 knots | 6.5 |
| Engines, two, four-cylinder, triple-expansion. | |
| diameter cylinders, inches—23, 34, 37 and 37; stroke | 22 |
| Boilers, four, Thornycroft, pressure, pounds | 240 |
| grate surface, square feet | 315 |
| heating surface, square feet | 17,768 |
| Propellers, three-bladed, diameter, feet | 8 |
| pitch, feet and inches | 11–3 |
| developed area, square feet | 22.7 |
| projected area, square feet | 17.14 |
| Weight, hull, on trial, tons | 218.09 |
| trial load, tons | 27.40 |
| machinery, on trial, tons | 204.92 |
| coal and water, on trial, tons | 42.20 |
| Total, tons | 492.61 |

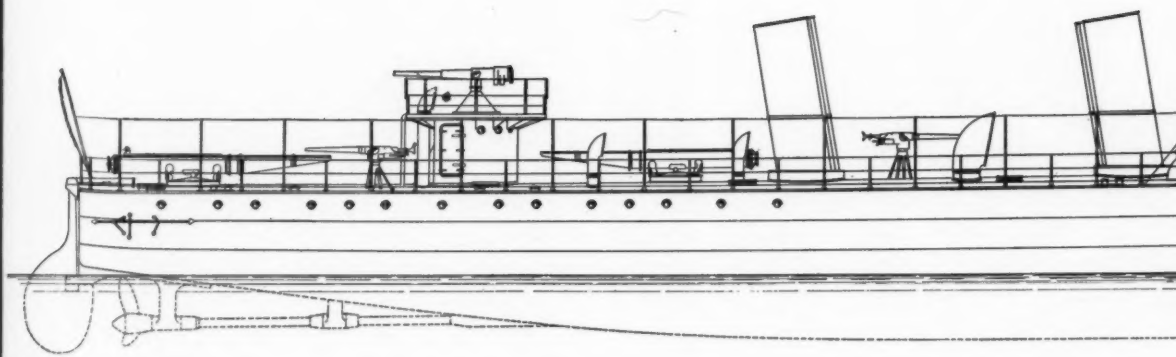
GENERAL DESIGN.

These boats and their machinery were built from the designs of the Maryland Steel Company, the Department's specifications being modified to suit the builders' plans. They are somewhat larger than any other of the sixteen destroyers, and larger than any foreign destroyers, except the twenty-five and one-half-knot English boats now being built.

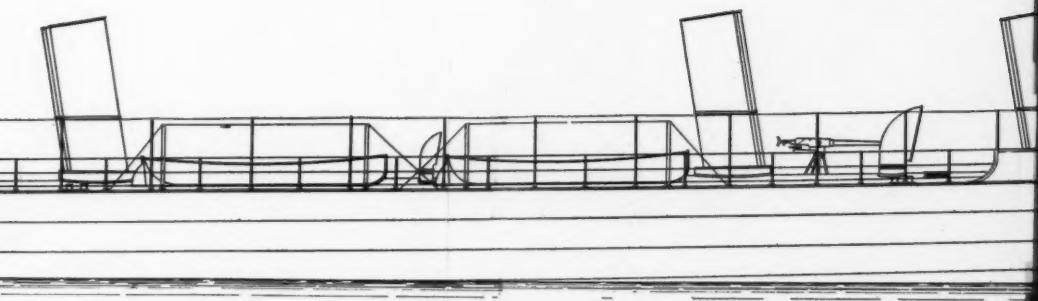
It was the intention in designing to make them as strong and durable, both of hull and machinery, in all essentials, as possible; while keeping the less important parts to a minimum weight, and it was early known that the sizes adopted made it out of question to keep near the specified four hundred and thirty-three tons displacement.

Wherever possible, effort was made to simplify things, in doing which the builders had the co-operation of the Department.

A minimum amount of wood was used, everything being metal except a portion of the furniture, and such furring and strips as were necessary to fasten the sheathing, the side sheathing itself being asbestos board on wire backing. All partitions were made

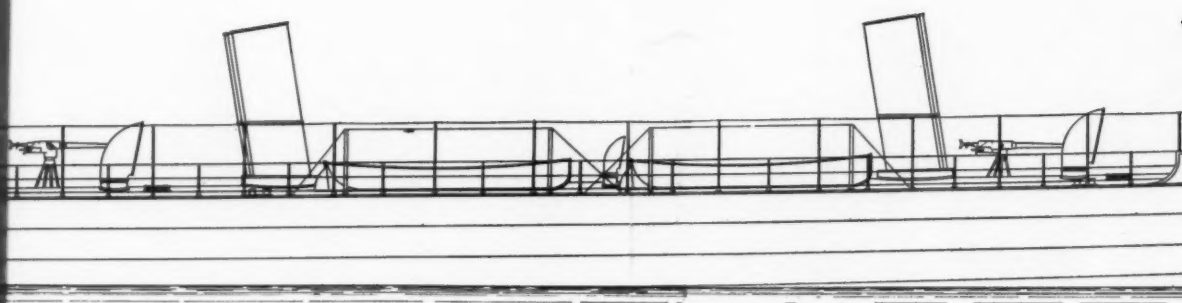


U. S. Torpedo-B



OUTBOARD PROFILE.

. TORPEDO-BOAT DESTROYERS "TRUXTUN," "WHIPPLE" AND "WORDEN."



OUTBOARD PROFILE.

U. S. TORPEDO-BOAT DESTROYERS "TRUXTUN," "WHIPPLE" AND "WORDEN."

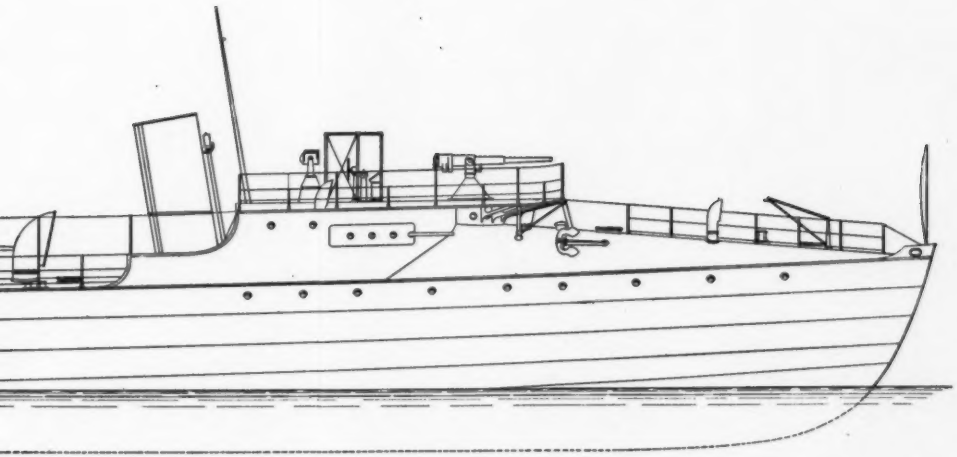
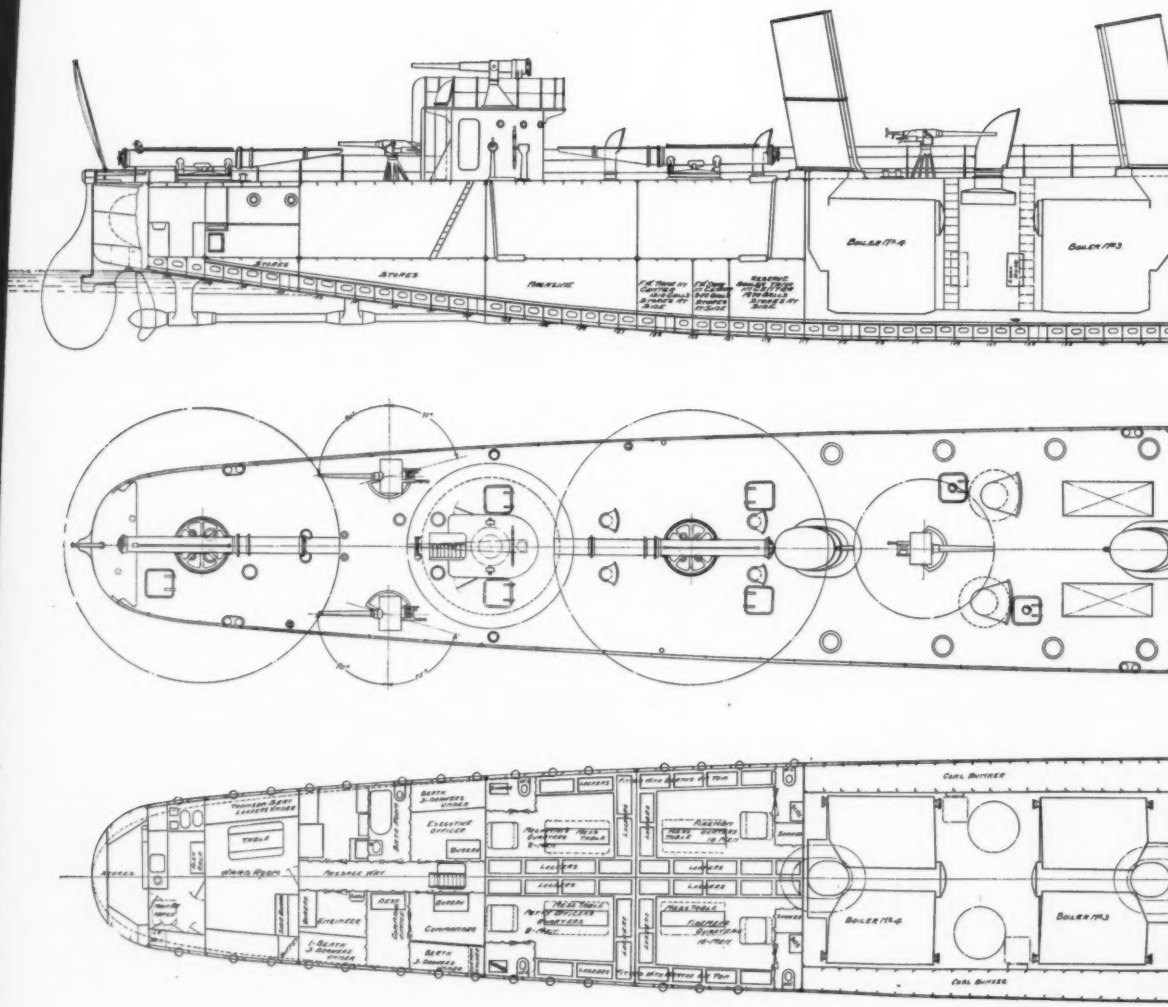
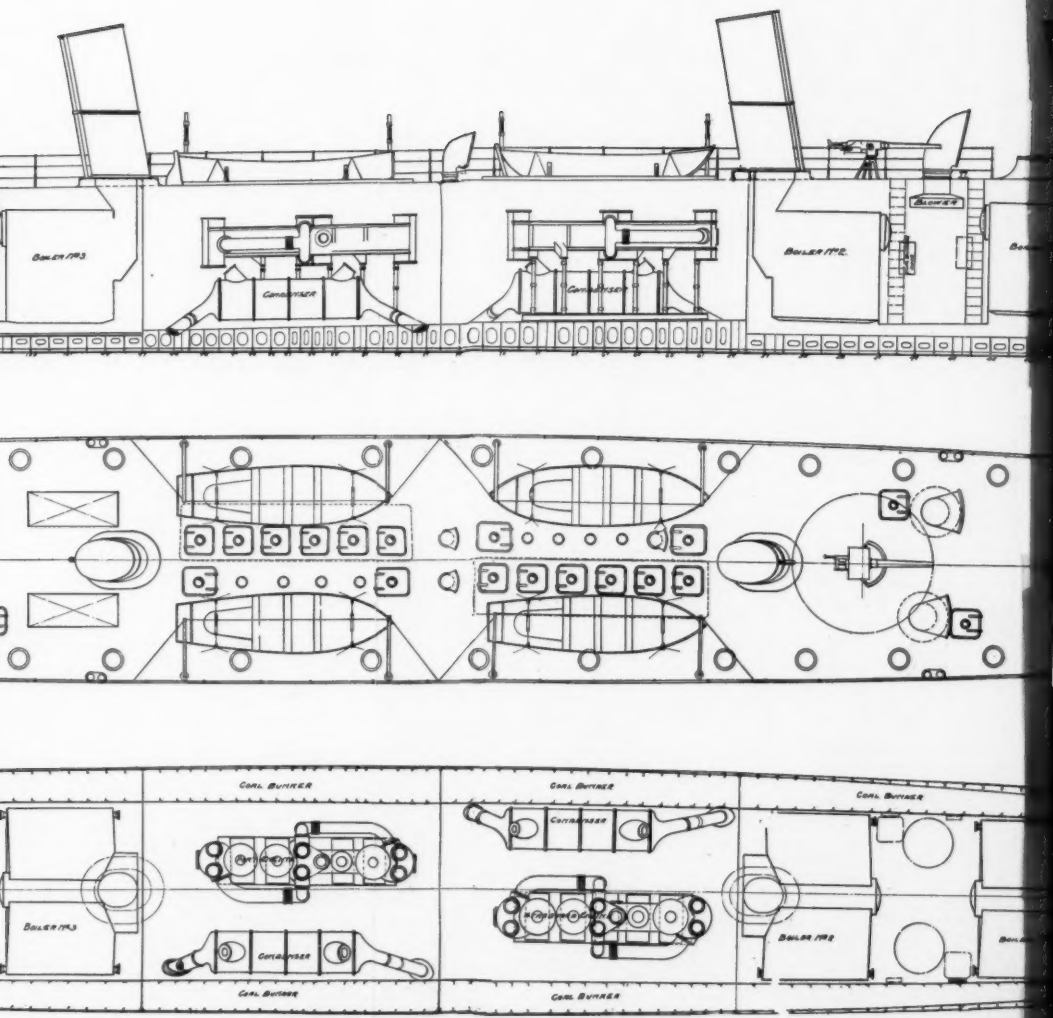


PLATE A.

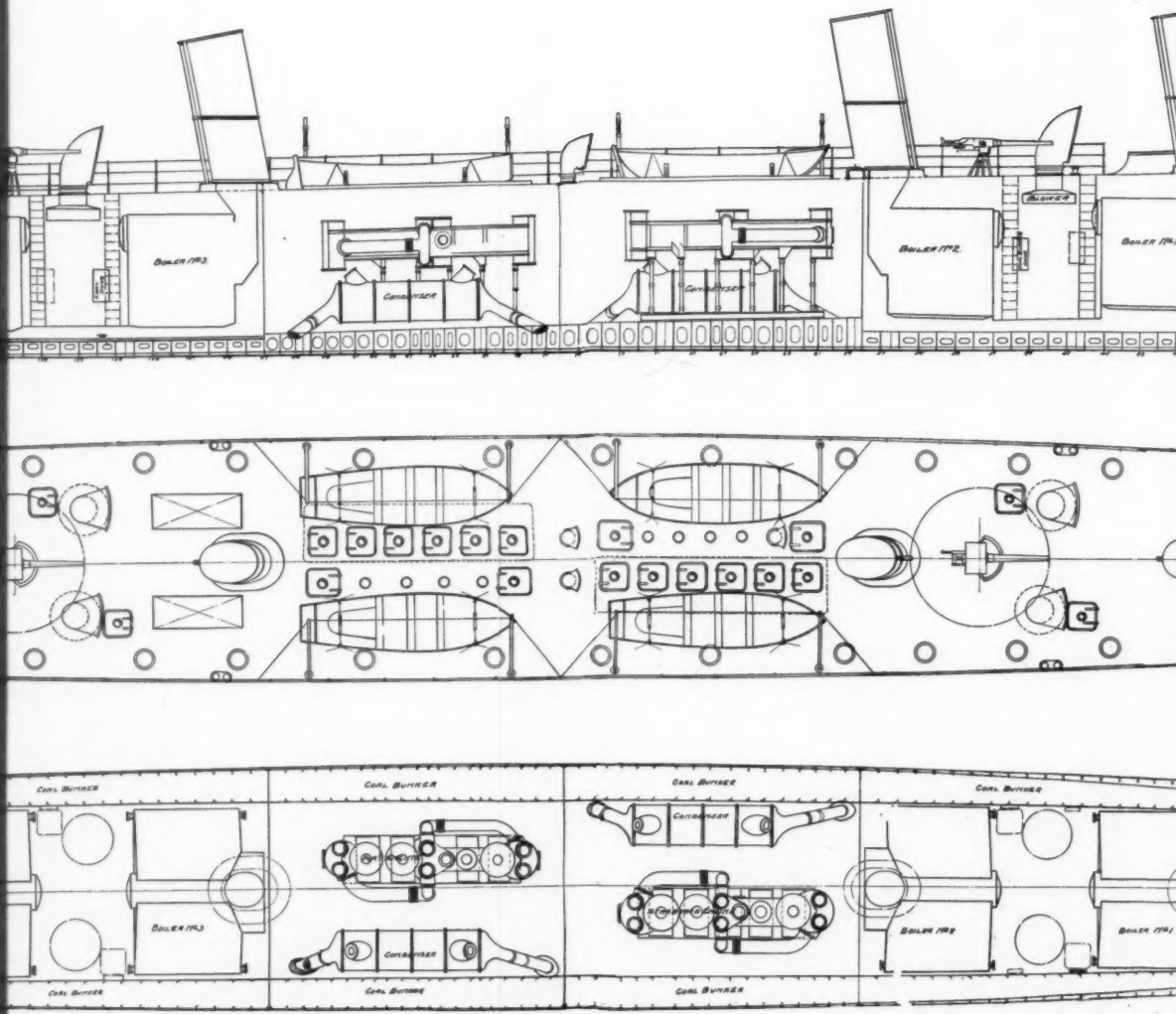

BOILER RM 4
BOILER RM 3
STORES
MAGAZINE
CURL BUTTRESS
BOILER RM 4
BOILER RM 3
CURL BUTTRESS

U. S. TORPED



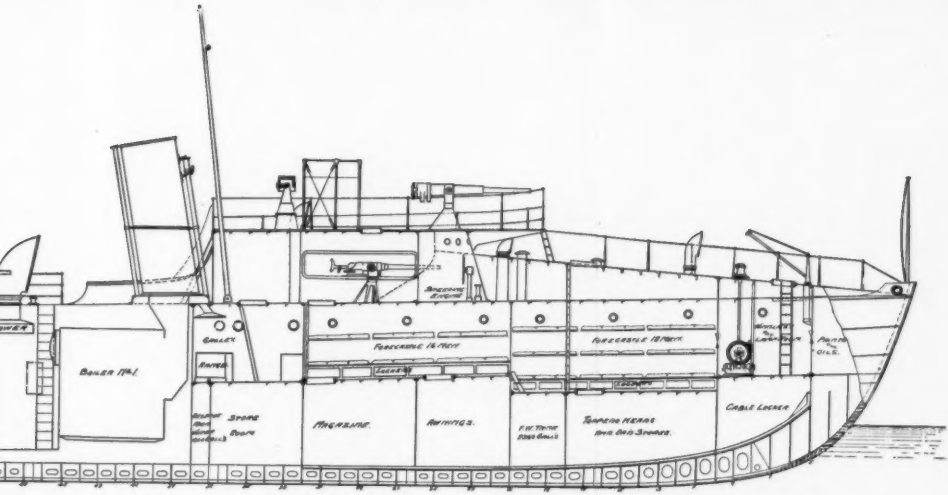

General Arrangement.

. S. Torpedo-Boat Destroyers "Truxtun," "Whipple" and "Worden."

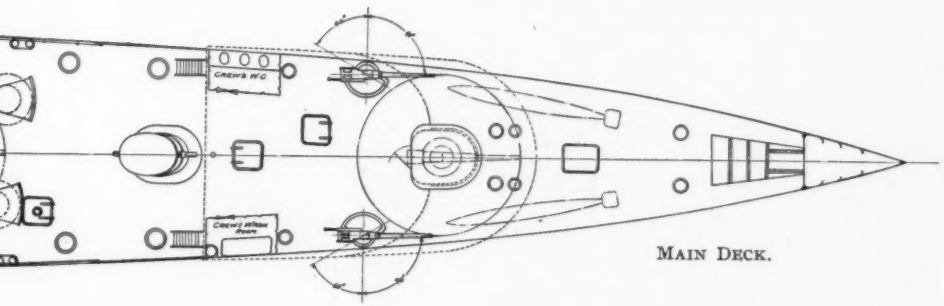



General Arrangement.

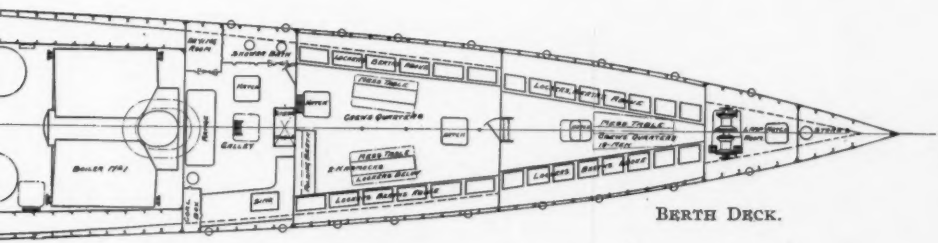
U. S. Torpedo-Boat Destroyers "Truxtun," "Whipple" and "Worden."




INBOARD PROFILE.




MAIN DECK.




BERTH DECK.

PLATE B.

of cor
racks.
Wh
and in
add w

The
plate),
ively
Unc
the bo
Aft
machi
entere
on eit
extend
room
For
quarte
fifteen
main c
magaz
Abo
tendin
deck.
castle
the ful
being a
profile
This
on dec
quarter
and it
which
kept ab

The
rapid-fi

of corrugated steel, as were also all doors, shelving and stowage racks.

Wherever gratings were required perforated steel was used, and in very few instances did the substitution of metal for wood add weight.

ARRANGEMENT.

The general arrangement shown by the plans, Fig. 3 (folding plate), and by the outboard and inboard profile, shown respectively on folding plates A and B, is briefly:

Under deck the engines are in the two center compartments, the boilers in the compartments next to them.

Aft of the machinery space are the firemen's quarters, then the machinists' and petty officers'. Next aft are the officers' quarters, entered from the after conning tower. The officers' rooms are on either side of a central passage which opens into a wardroom extending the full width of the vessel, having a pantry and storeroom in the extreme after end of the vessel.

Forward of the machinery space is the galley, then the crew's quarters, windlass compartment and fore peak, making in all fifteen watertight compartments with bulkheads extending to the main deck. Below the lower deck are the various store rooms, magazines and tanks.

Above the main deck are the two conning towers, and extending from the forward conning tower to the stern is a turtle deck. From this conning tower to the forward stack a forecastle deck is carried at the level of the lower tops, extending the full width of the vessel, with the sides enclosed, the after end being aft open, as shown in photograph, Fig. 1, and by outboard profile shown in folding plate A.

This is an especial feature of these boats, as it affords shelter on deck in bad weather, gives ventilation to the galley and crew's quarters, it being possible to keep the hatches up at all times, and it also gives room for the crew's water closet and wash room, which are at the after part on either side and are by this means kept above deck.

ARMAMENT.

The armament is two 18-inch torpedo tubes aft, two 3-inch rapid-firing guns on the conning towers, and six 6-pounder semi-

automatic guns on deck, this being a somewhat heavier armament than published data gives for other destroyers.

### HULL, SPECIAL FEATURES.

The design of the hull can best be referred to by a few comparisons with the original specifications.

The shapes generally are deeper and ten per cent. heavier, floors two pounds heavier, shell plating generally ten per cent. heavier. The general plan of scantlings is as indicated in midship section, Fig. 2 (folding plate).

Additional strength has also been worked into the longitudinal bunker bulkheads, which are continuous for the whole length of the machinery space, and additional bulkhead stiffening has been provided.

The engine foundations are heavier, and the shaft struts, which are much stiffer than in other boats of the class, are secured to the outside of the hull, the feet being carried for a considerable distance fore and aft and adequate stiffening provided inside, all of which has made very strong and steady hulls, which are far from being the "tin pot" affairs of popular conception.

The galvanizing has also been carried to a much greater extent than originally specified, and there is no part of the hull which is not accessible for cleaning and painting.

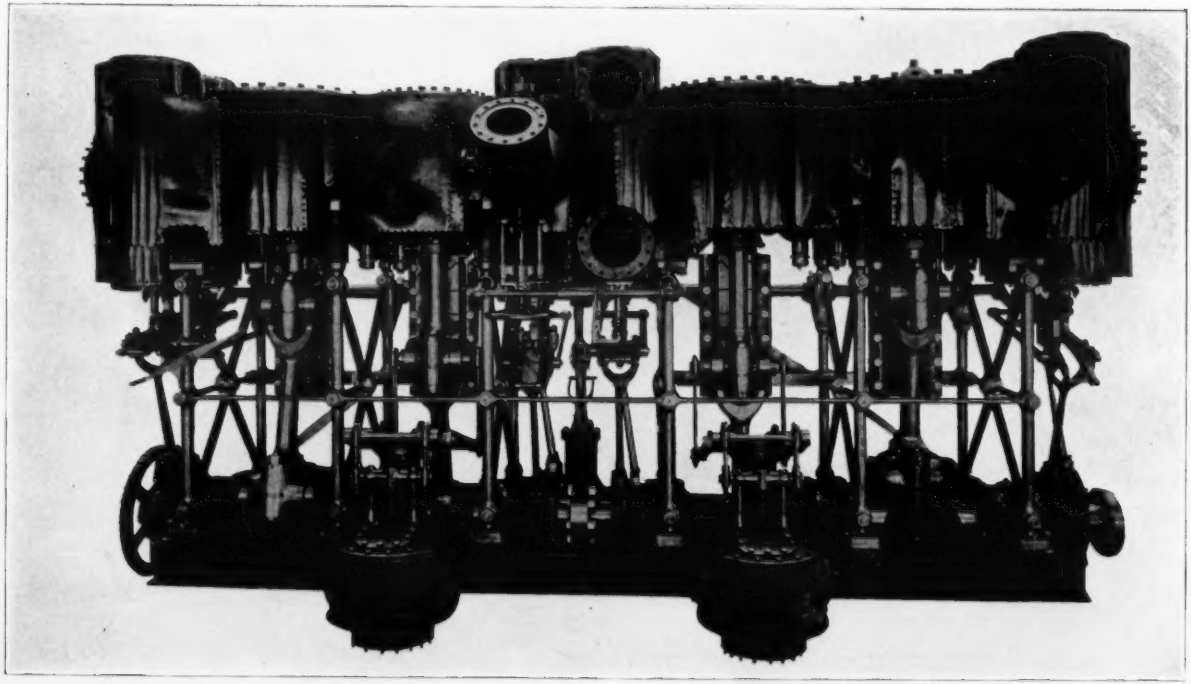
In the way of fittings, very complete ventilation has been provided, the hatches are much larger than is usual, and a large number of coal scuttles make it possible to coal with the minimum amount of trimming.

The steering engine, built especially for these boats, is less than half the weight of that in use on various other destroyers, while of the same power, and has proved very durable.

### MACHINERY.

Thornycroft boilers of the *Daring* type, four in number, are arranged in two independent sets, two boilers in a compartment, each set having two blowers 57 inches in diameter and two feed pumps; also an ash ejector. No reducing valves are used.

The steam pipes of drawn steel are arranged in a simple man-



STARBOARD ENGINE OF "WORDEN"—U. S. TORPEDO-BOAT DESTROYER.

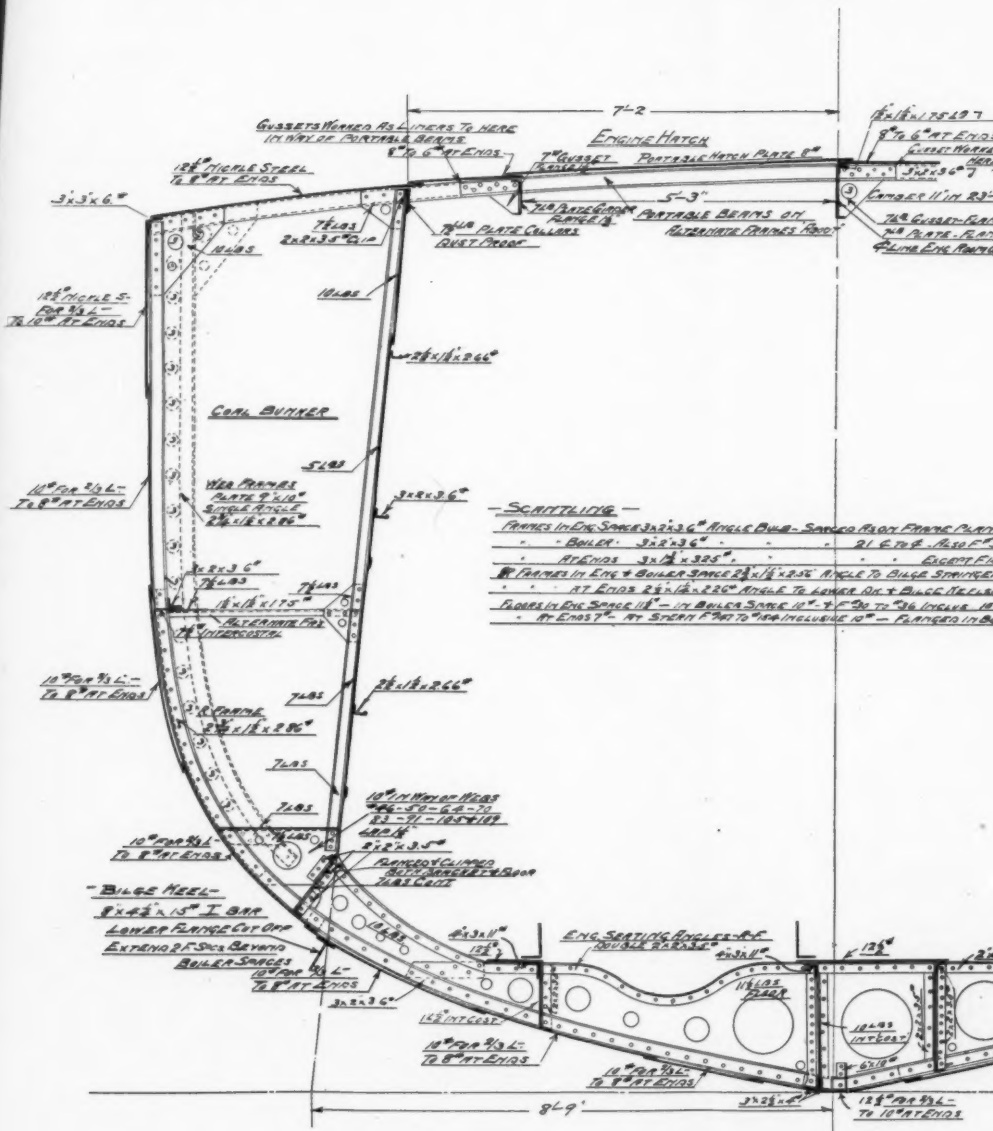
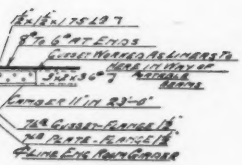
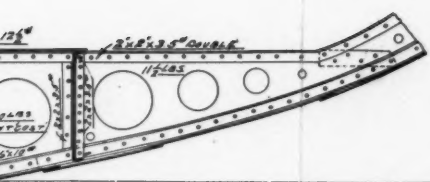
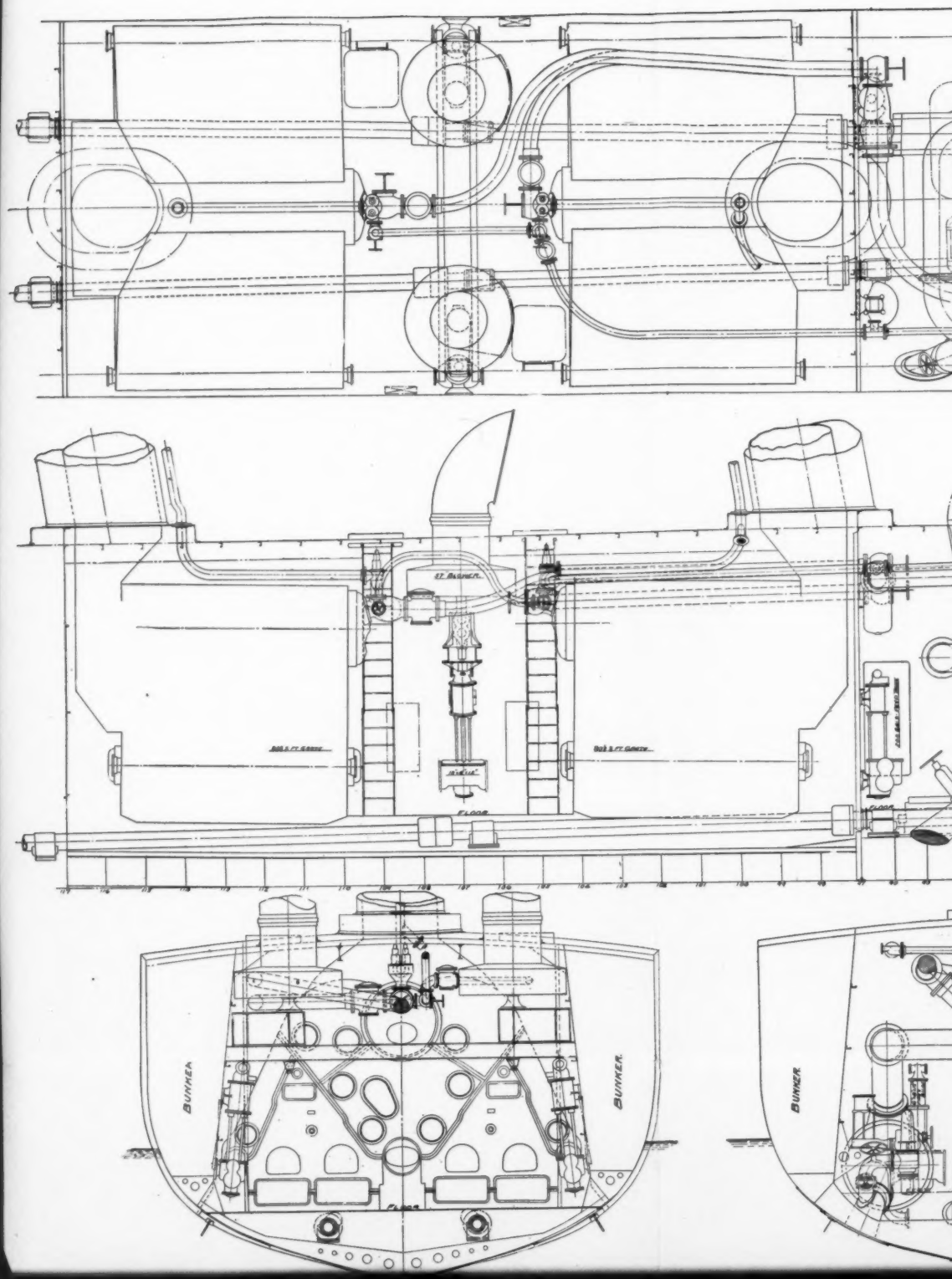


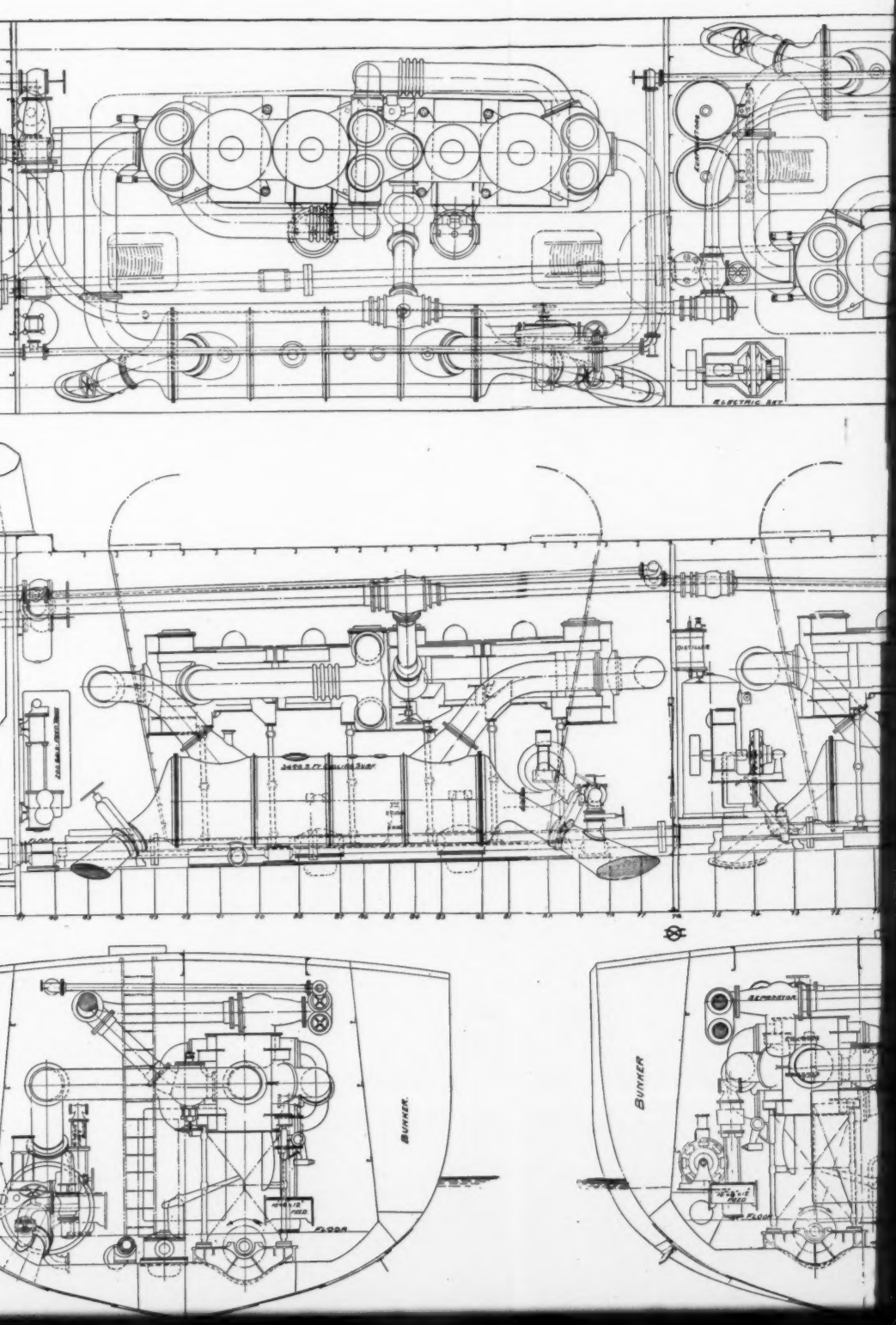

FIG. 2.—Midship Section of "Truxtun," "Whipple" and

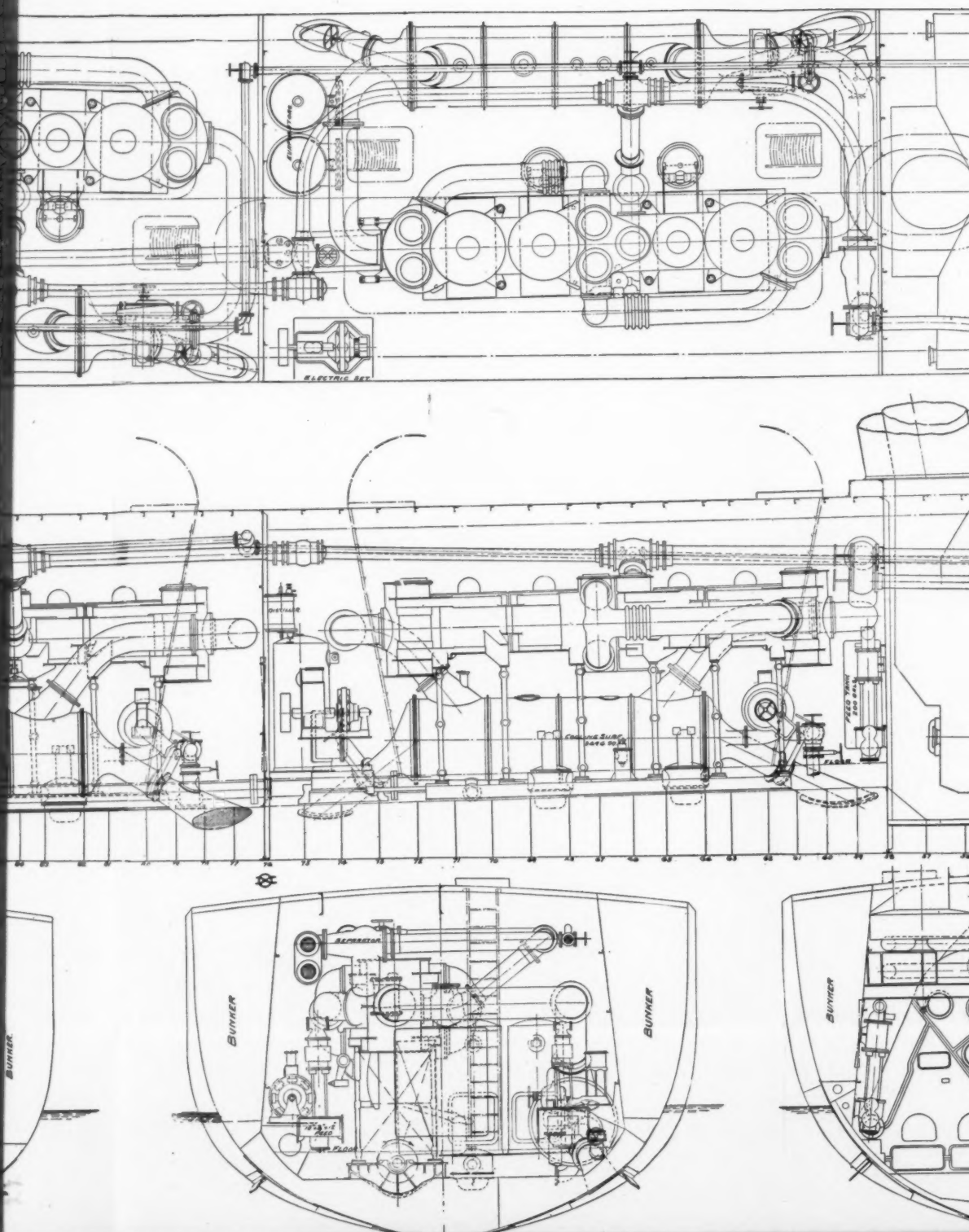




PPLE" AND "WORDEN."


ST. BURNER.
FLOOR
BUNKER
BUNKER
FLOOR
BUNKER


ELECTRIC SET
DISTILLER
BUNKER
BUNKER
EVAPORATOR


ELECTRIC SET
DISTILLER
COOLING SUCT. PATG. 50
FEED TANK 100 GALS.
SEPARATOR
BUNKER
BUNKER
BUNKER

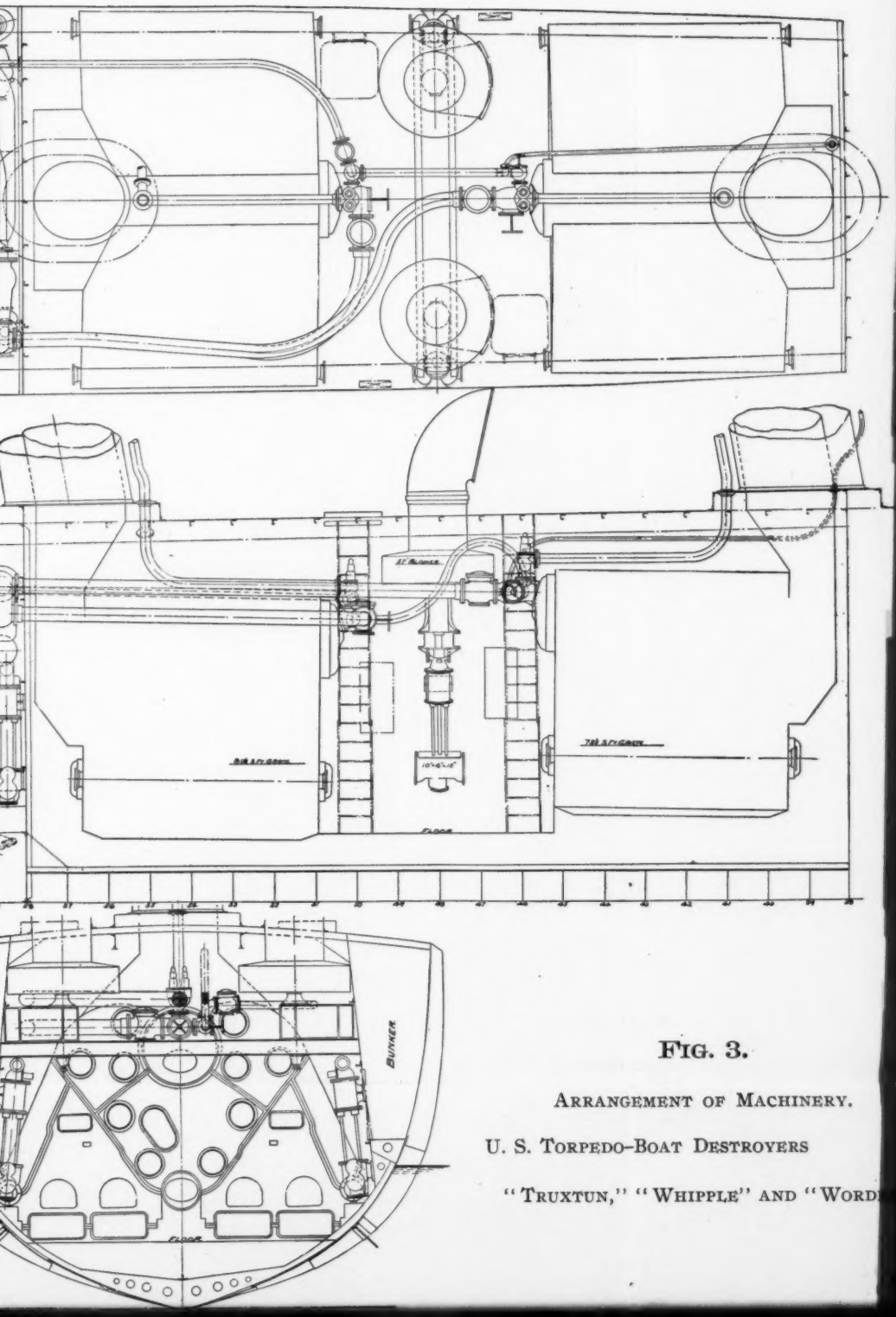
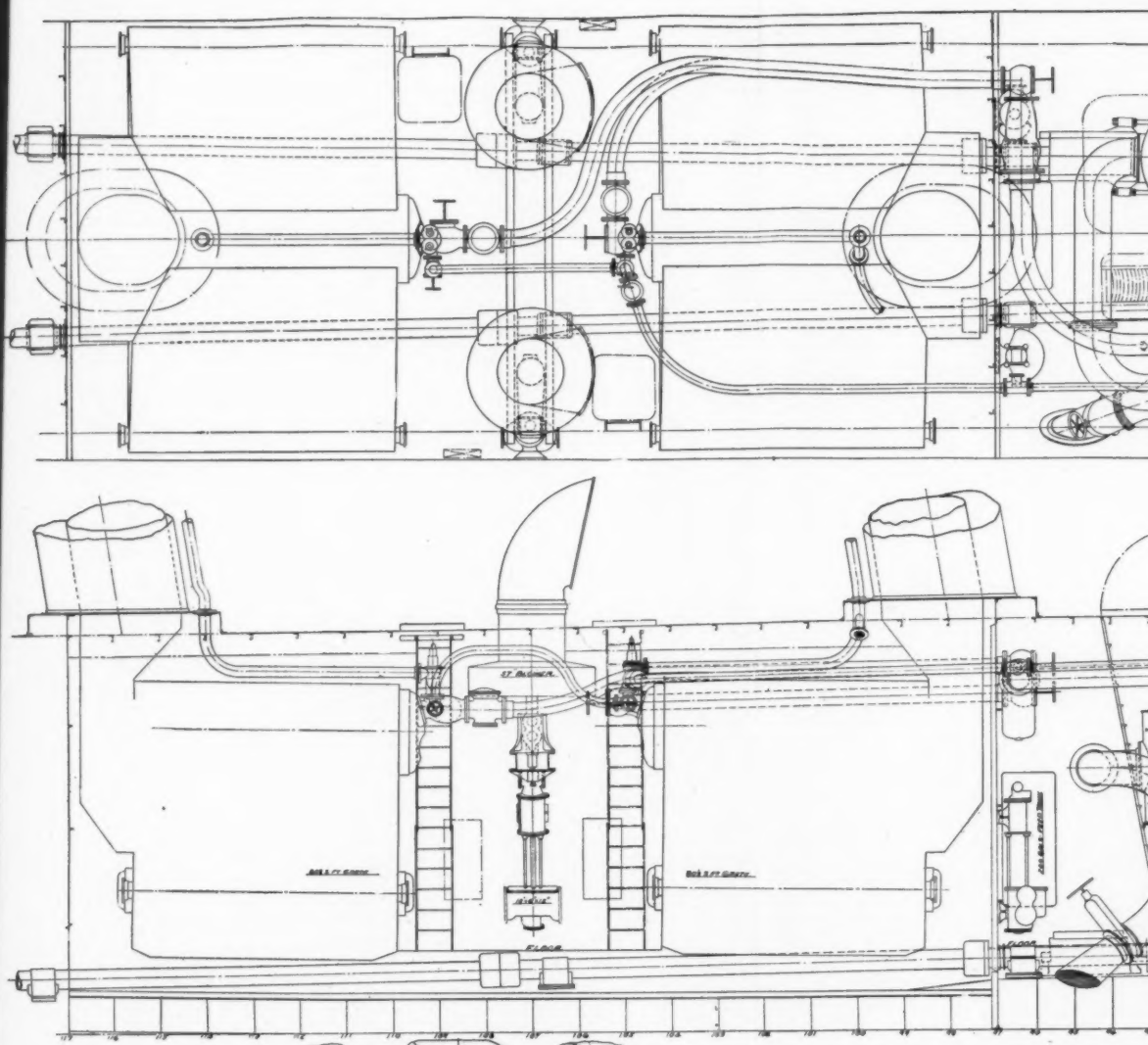



**FIG. 3.**

ARRANGEMENT OF MACHINERY.

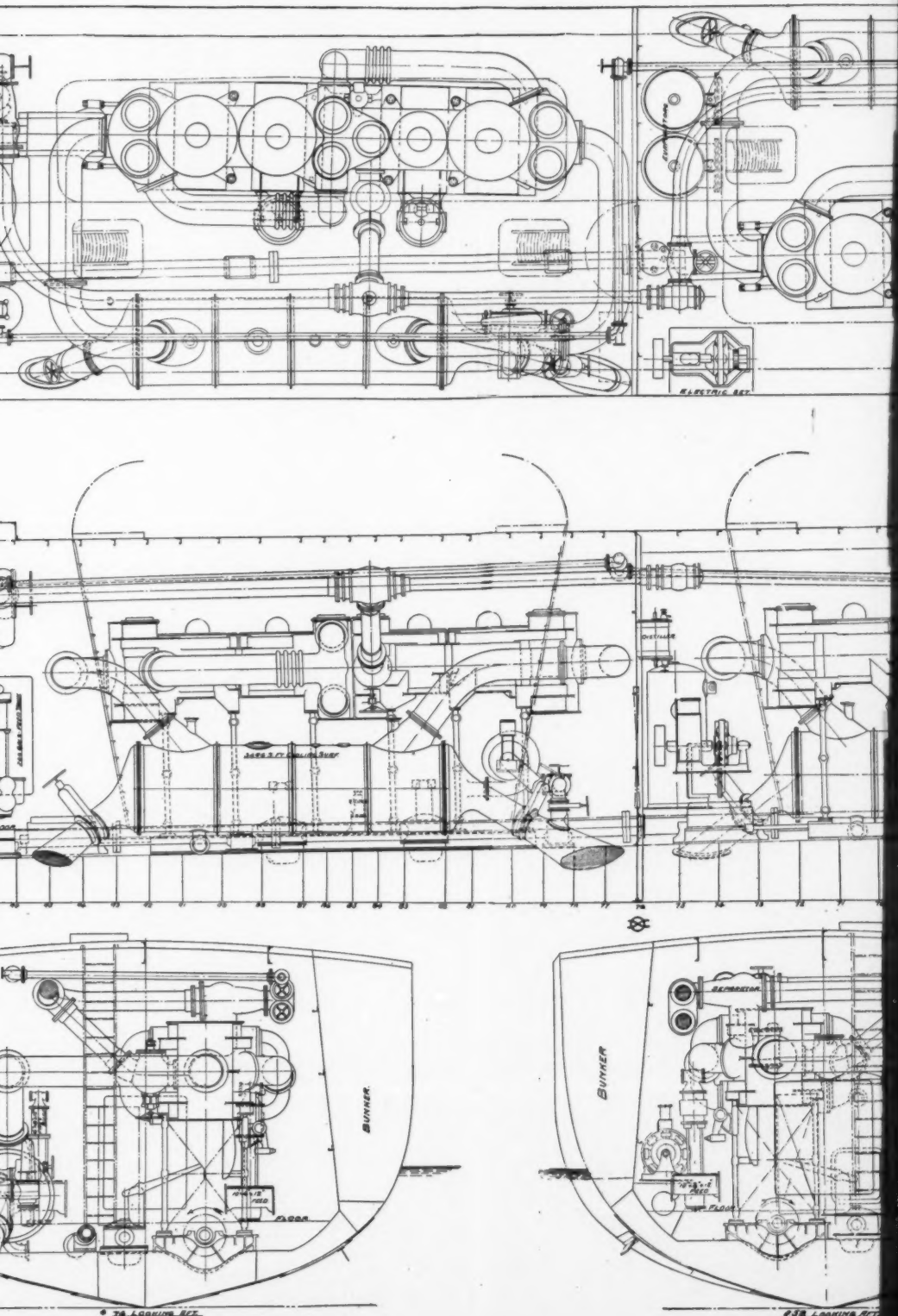
U. S. TORPEDO-BOAT DESTROYERS

"TRUXTUN," "WHIPPLE" AND "WORDE



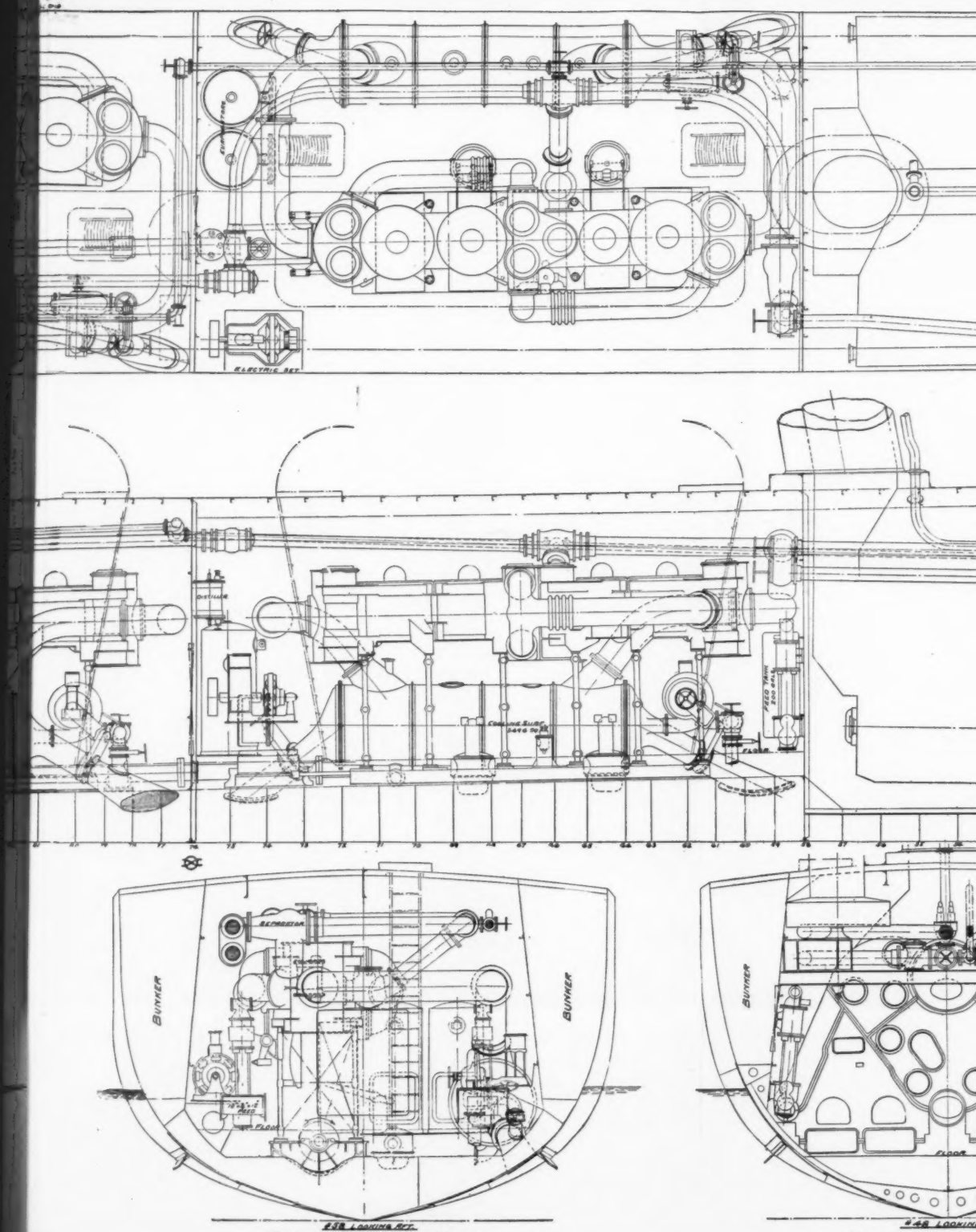

AFTER STOKEHOLD.

MIDSHIP SECTION



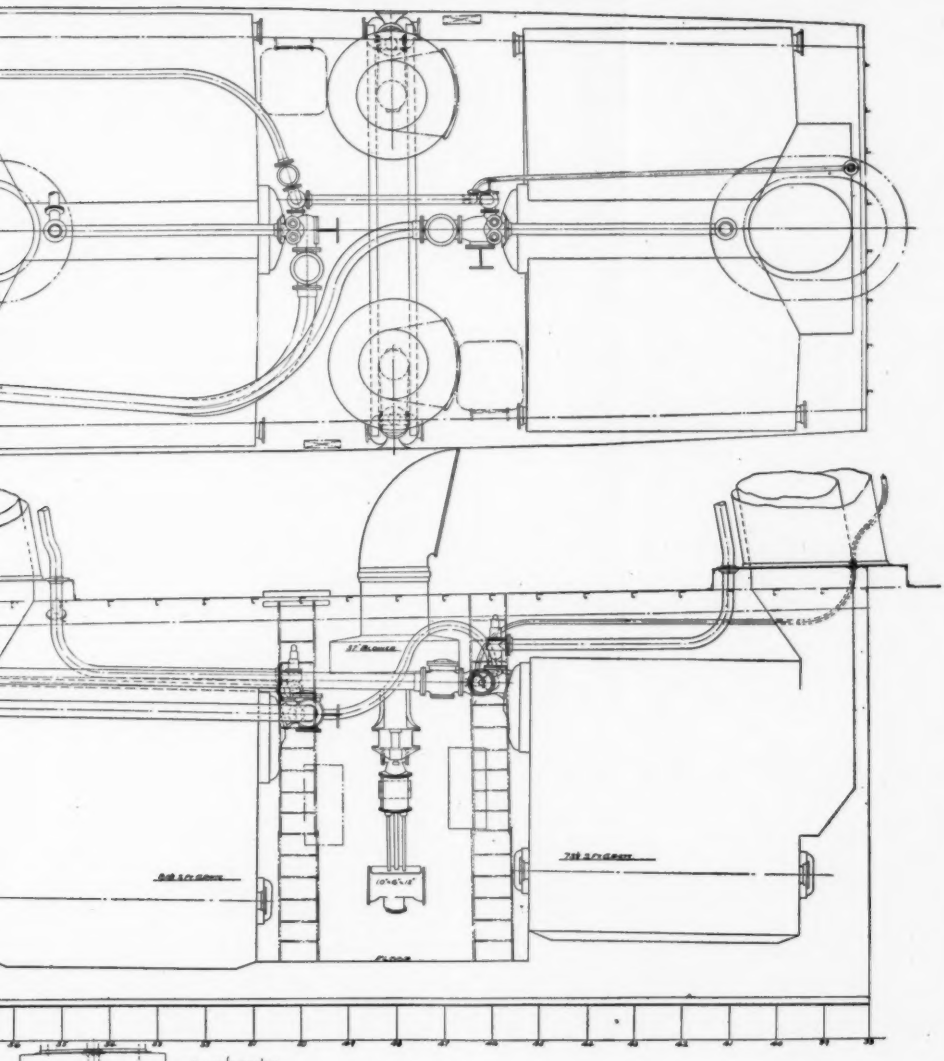

SHIP SECTION—AFTER ENGINE ROOM.

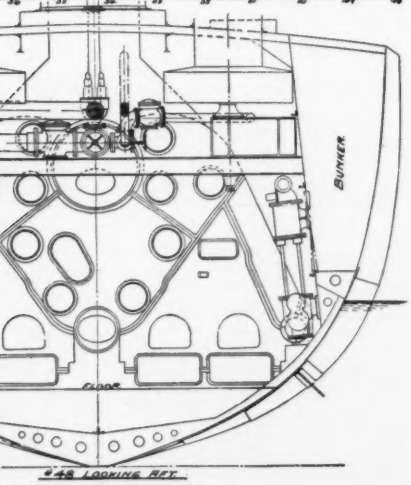
FORWARD ENGIN




FORWARD ENGINE ROOM.

FORWARD STO





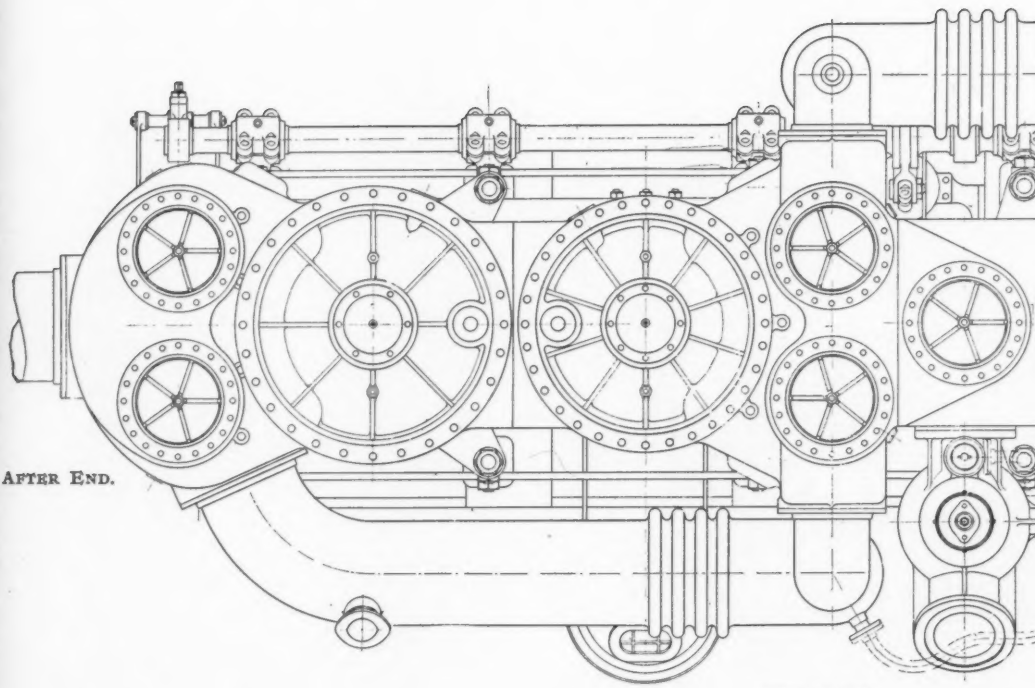

ORWARD STOKEHOLD.

**FIG. 3.**

ARRANGEMENT OF MACHINERY.

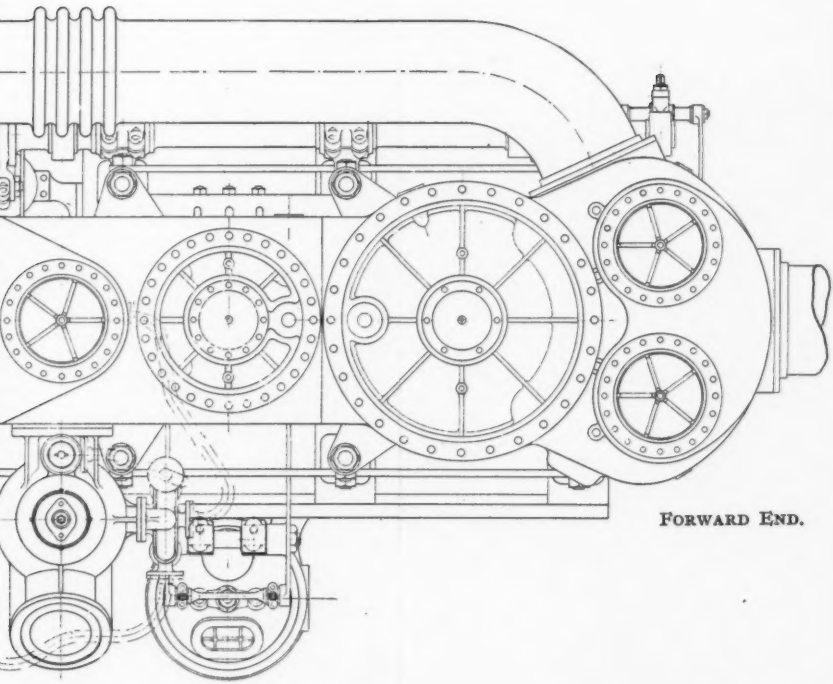
U. S. TORPEDO-BOAT DESTROYERS

"TRUXTUN," "WHIPPLE" AND "WORDEN."



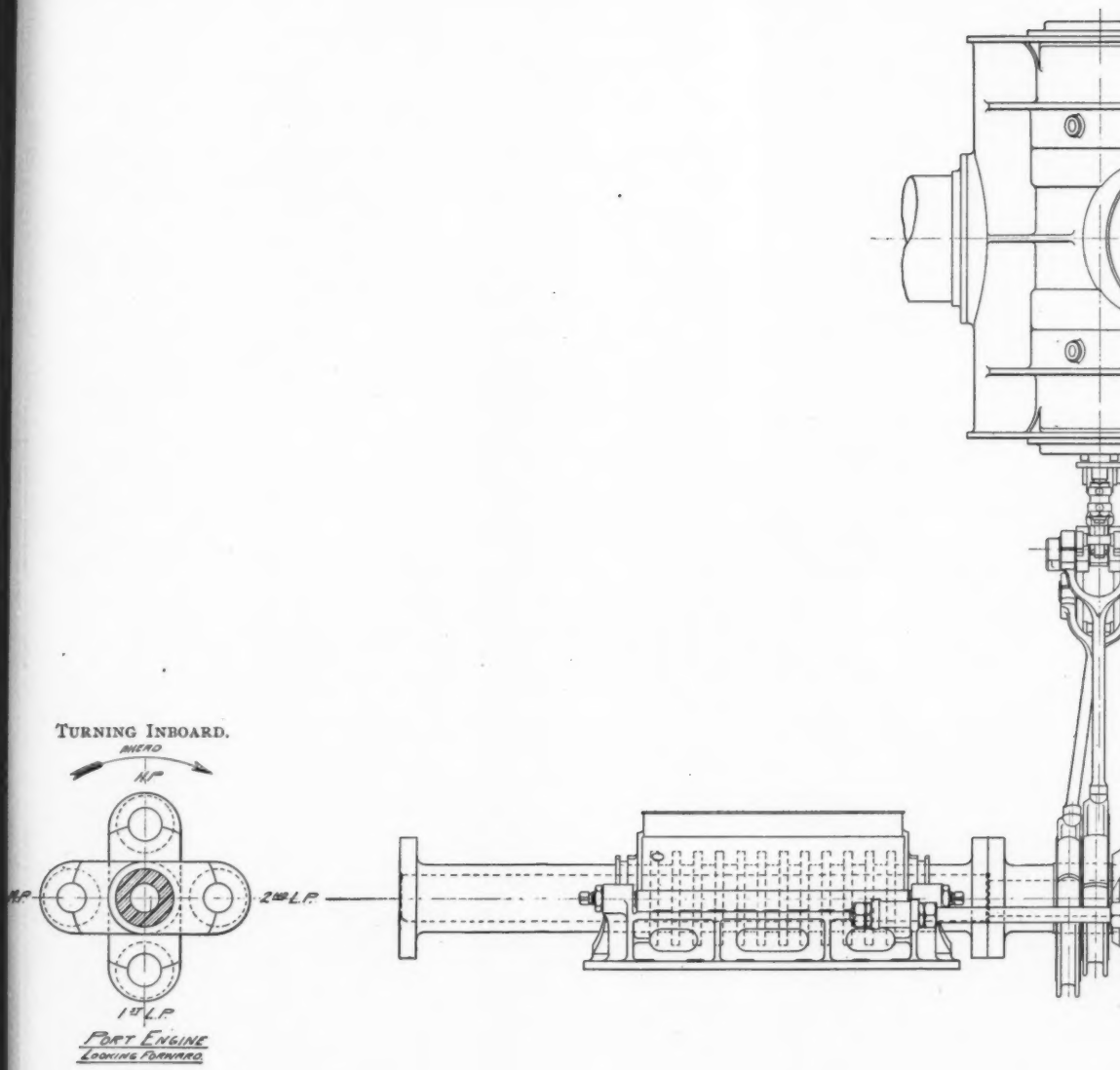

PLAN.

FIG. 4.—Cylinder and Valve Arrangement of Main Engines, U. S. Torpedo-Boat



FORWARD END.

RPEDO-BOAT DESTROYERS "TRUXTUN," "WHIPPLE" AND "WORDEN."


TURNING INBOARD.
INBD
H.P
H.P
2nd L.P
1st L.P
PORT ENGINE
LOOKING FORWARD.

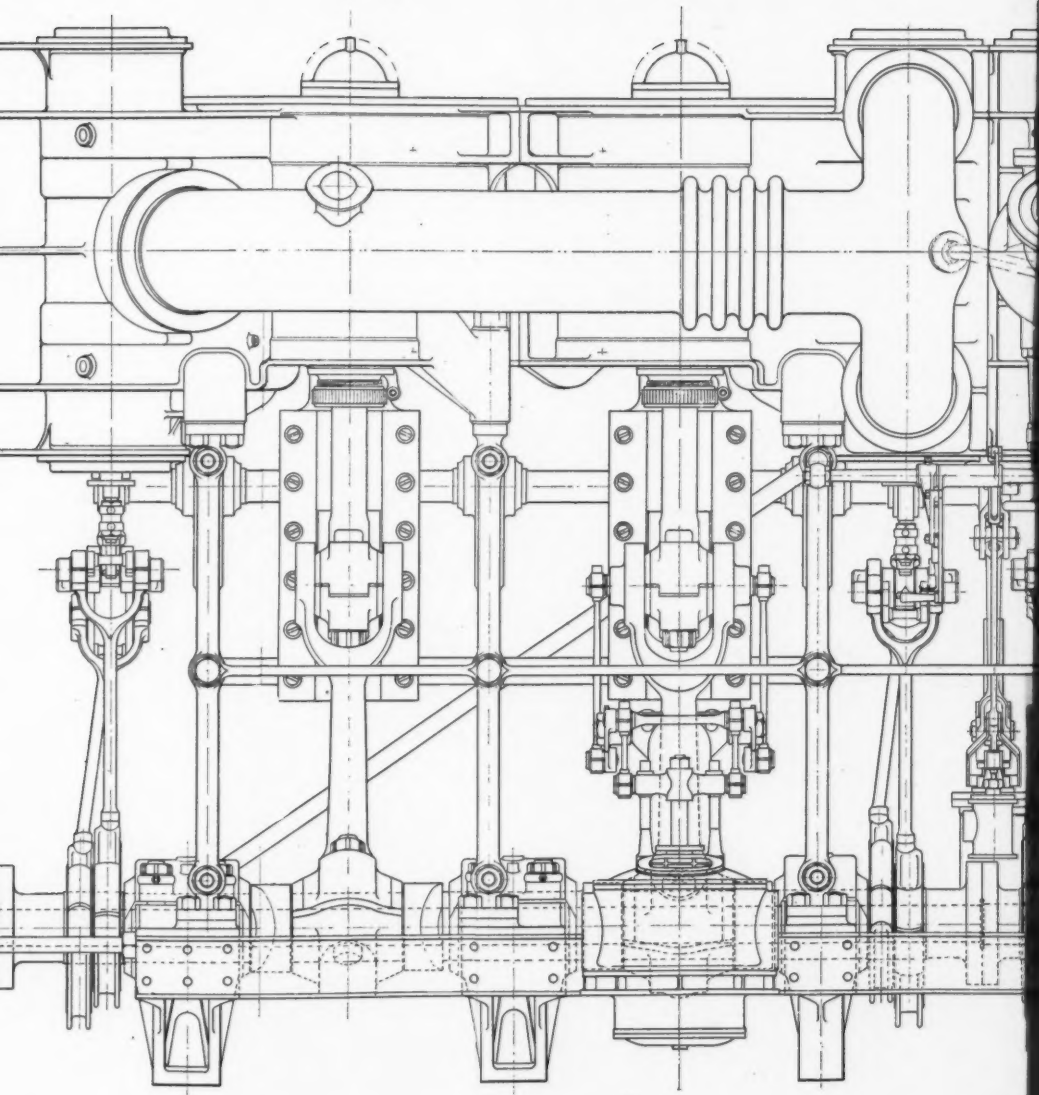
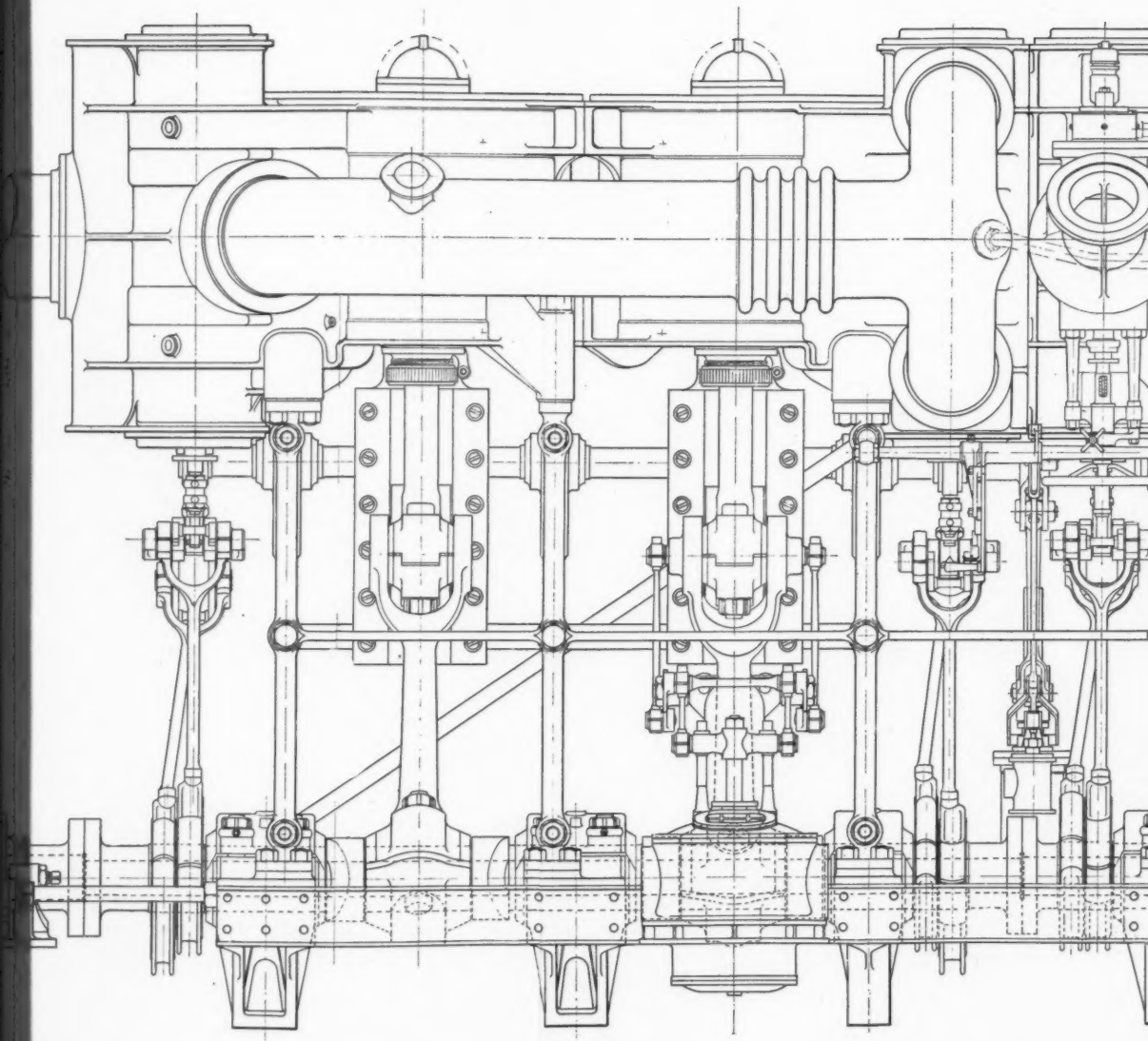
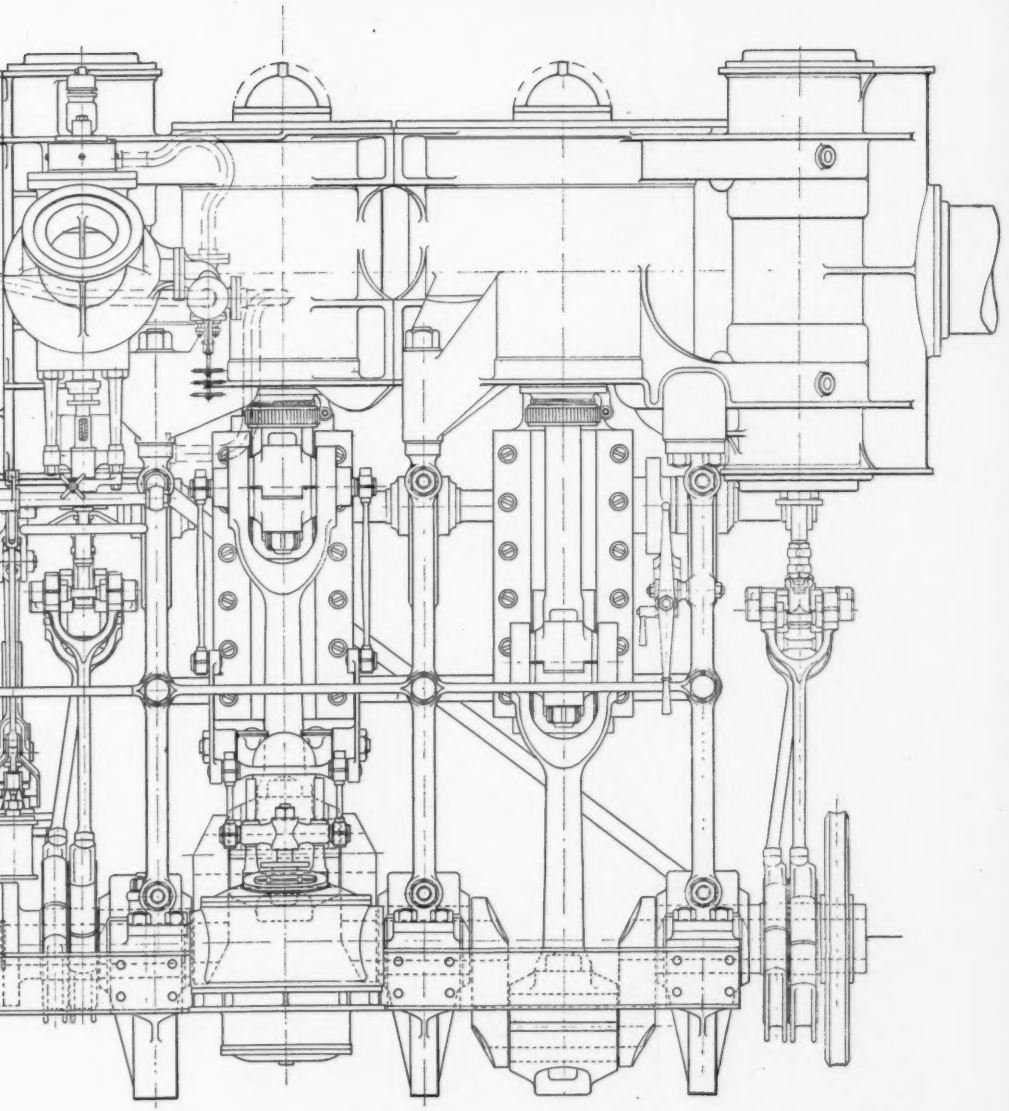



FIG. 5.—Arrangement of Main Engines of U. S. Torpedo-Boat



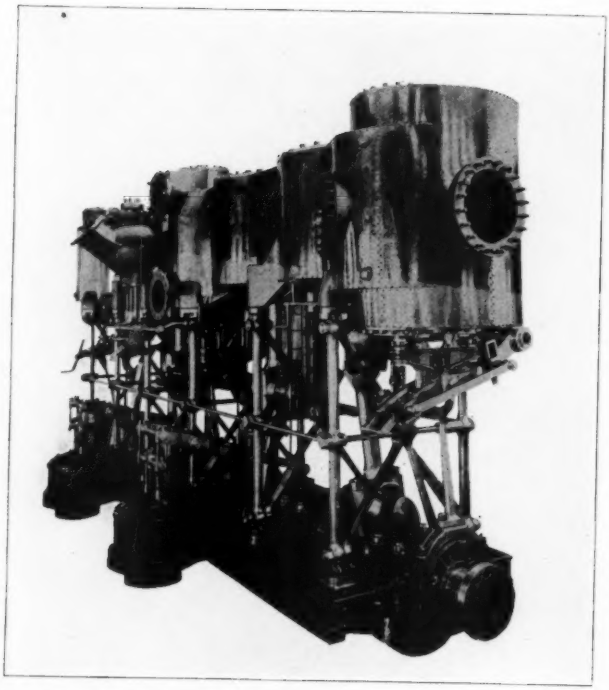
ELEVATION OF PORT ENGINE

FIG. 5.—ARRANGEMENT OF MAIN ENGINES OF U. S. TORPEDO-BOAT DESTRO



- PORT ENGINE

OAT DESTROYERS "TRUXTUN," "WHIPPLE" AND "WORDEN."



STARBOARD ENGINE, U. S. S. "WORDEN," AFTER END.

ner to take expansion, there being but three slip joints on a boat. These are of a plain balanced type and require no bracing, the whole arrangement being a marked contrast to a well-known foreign type in which there are no less than eleven slip joints between boilers and engines, all of which require elaborate bracing. The fire rooms are entirely clear of ladders and stanchions, and the firemen expressed considerable satisfaction with the arrangement.

The engines, as compared with the original specifications, have larger high-pressure and medium-pressure cylinders and smaller low-pressure cylinders, the valves being duplicates for all cylinders, the general arrangement and position of valves and cylinders being shown on Fig. 4.

The framing and bracing is arranged in a manner similar to that used on recent battleships, giving great rigidity. Details of framing and general arrangement of engines are shown in Figs. 6 and 7, and Fig. 5, folding plate, and by the photographs of starboard engine, showing side and end views.

The connecting rods, piston rods and crank shaft were kept large, as well as the remainder of the shafting.

The line and propeller shafting being about eight per cent. more in diameter than original requirements, and the axial hole being enlarged, a considerable increase in strength and saving in weight resulted, no torsional vibration being perceptible. All of this has led to but a slight increase in weight over the 198 tons allowed.

### ENGINE-ROOM ARRANGEMENT.

A distinctive feature is the engine-room arrangement.

The air pumps, driven from the H.P. and M.P. cylinders, are placed at the front of the engines and the condenser is made of somewhat smaller diameter and greater length than usual. The floor is raised sufficiently to cover the shafting (giving a continuous floor without breaks), and the auxiliaries are so arranged that there is a clear space at the back as well as the front of the engine, and everything can be handled from the floor.

At the back of the engines a convenient and easily accessible grating is arranged for working the indicators.

The effect of all this is that an average man can walk com-

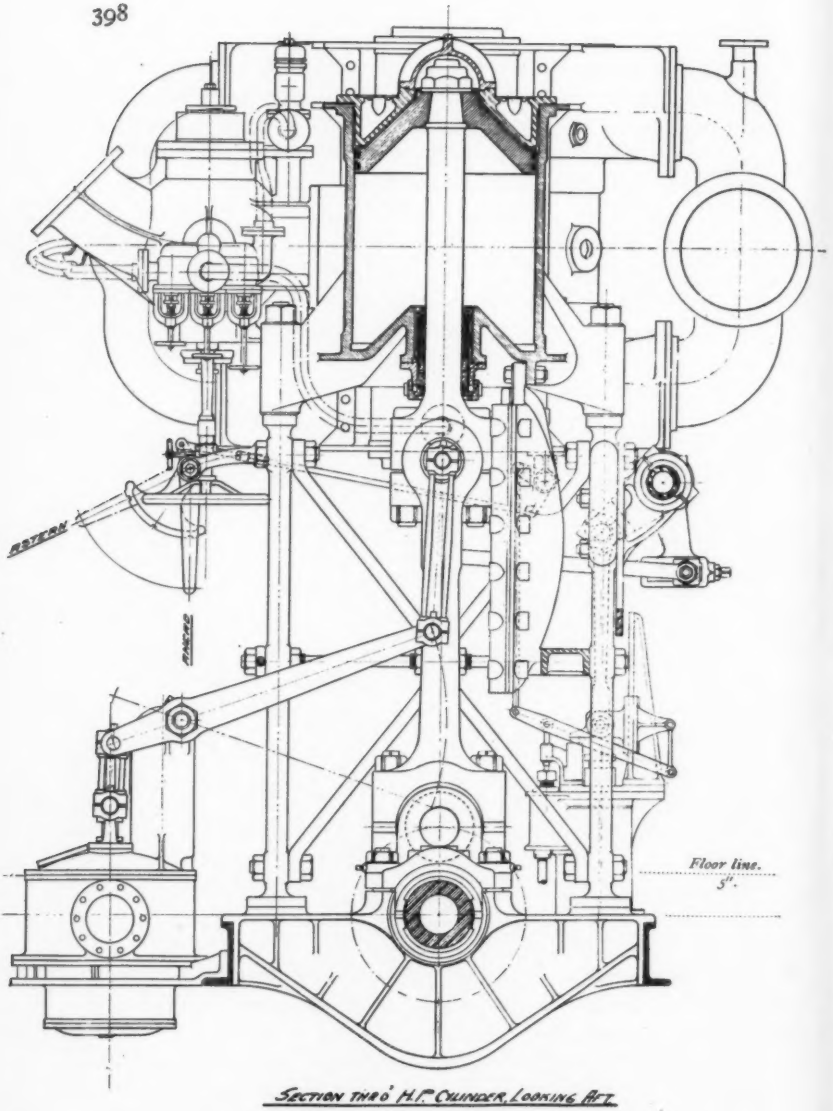



FIG. 6.—PORT ENGINE.

pletely around either engine without dodging any obstruction or ducking his head, a result that is not believed to have been elsewhere obtained on this class of boat.

The machinery also, although arranged for inboard turning, is equally adapted to outboard-turning screws.

### TRIAL PERFORMANCE.

The distribution of horsepower on trial was quite even, and an especially good adjustment of machinery was noticeable on the hour's run of the *Worden*, when both engines being run with the throttle wide and all boilers connected, the resulting average revolutions per minute were 311.35 port and 311.55 starboard.

During the latter part of the hour the number of revolutions for each five-minute observation were the same on both engines.

There was a marked absence of vibration, especially at the higher speeds, and very small change of trim, as will be seen from the photograph obtained at thirty knots speed (Fig. 1).

The results of the builders' trials are given in tabular form and by curves in Fig. 8, while Fig. 9 indicates corresponding facts obtained from the official runs.

### EFFICIENCY.

The efficiency of the boats seems good. At twenty-eight knots the indicated horsepower per ton of displacement is 14.378, and per one hundred square feet of wetted surface, 134.469. The indicated horsepower per ton at twenty-eight knots of the only other U. S. torpedo-boat destroyers at hand being 16.063 and 14.937, and of the best type of torpedo boat 21.26 per ton and 140.63 per hundred square feet of wetted surface.

### STEAMING RADIUS.

The net bunker capacity at 42 cubic feet per ton, with allowance for stowage, is 180 tons.

This coal will give a steaming radius of 2,100 miles for the bunkers, based on recent actual destroyer performance, and can be readily increased to 2,700 miles by coal that can be carried in addition to the above.

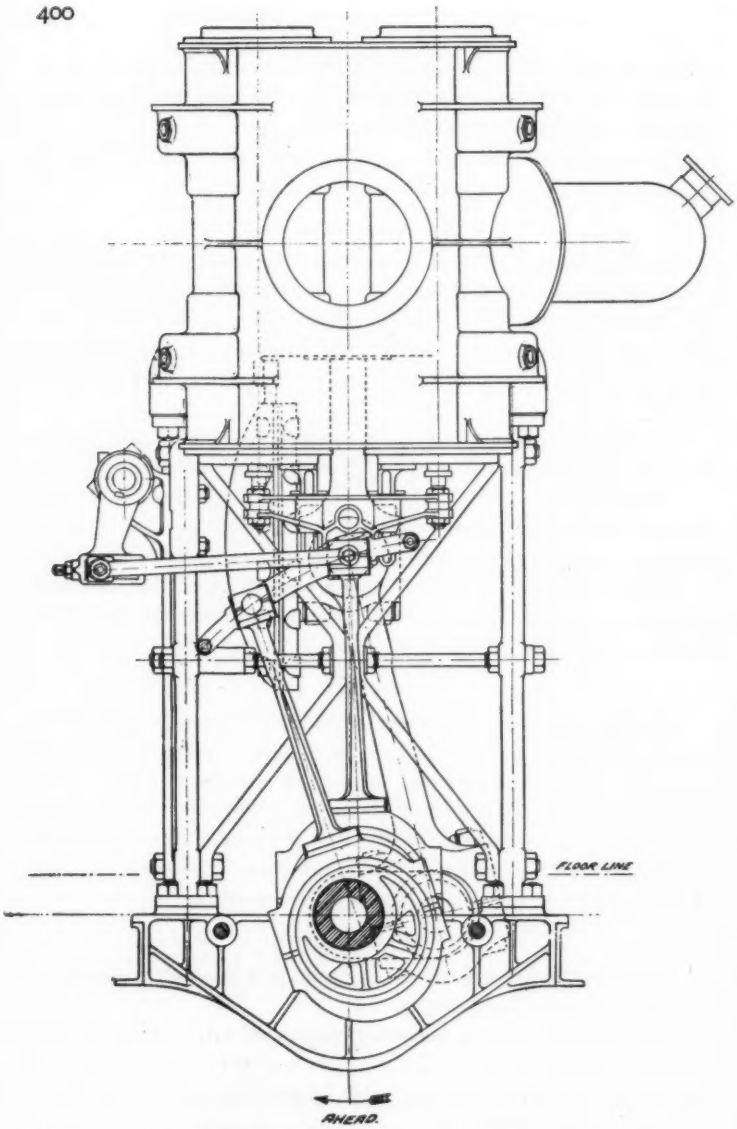



**FIG. 7.**—PORT ENGINE.

The bunker capacity itself is greatly in excess of that given for foreign boats, making all due allowance for difference in power.

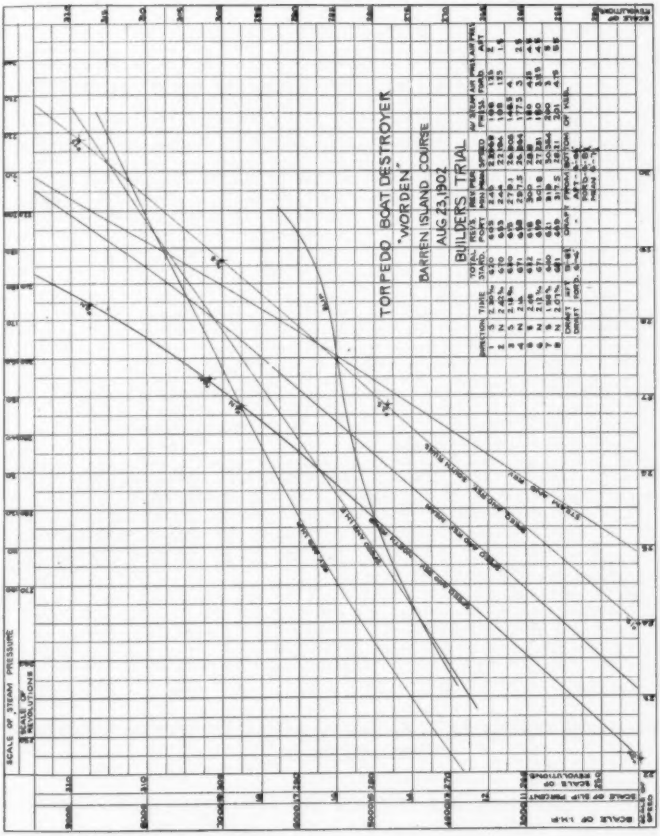



FIG. 8.—SPEED CURVES OF U. S. TORPEDO-BOAT DESTROYER "WORDEN." BUILDERS' TRIAL.

Tank capacity is 3,170 gallons reserve feed water and 4,520 gallons drinking water.

BASIS OF DESIGN FOR LARGER BOATS.

It is believed that further experience will show the type of boat to be such as to afford a most excellent basis for development into a class of larger sea-going destroyers or scout boats,

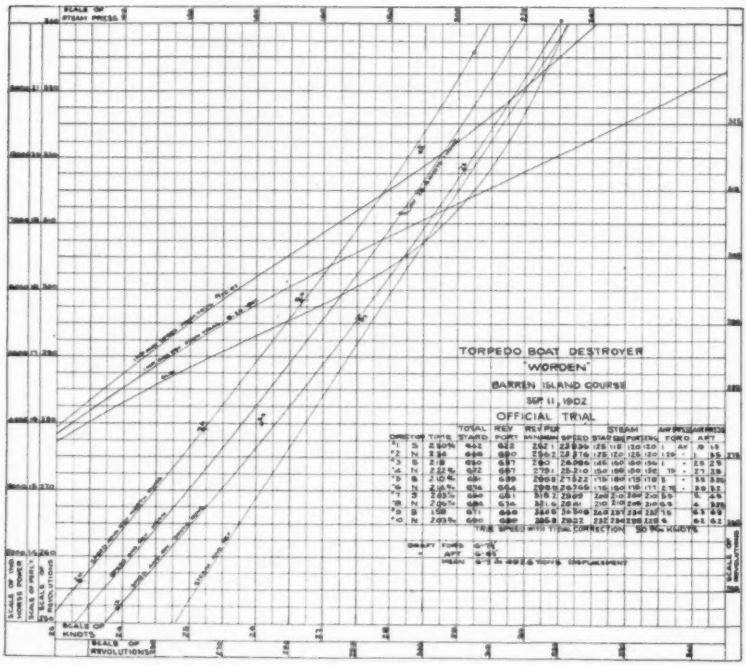



**FIG. 9.**—SPEED CURVES OF U. S. TORPEDO-BOAT DESTROYER "WORDEN." OFFICIAL TRIAL.

and the Department has selected the *Truxtun* to make a series of speed and endurance runs at full loaded condition to obtain complete information and data. The runs over the measured mile have already been completed very satisfactorily.

NO DIFFICULTY IN CONSTRUCTION.

On account of the general impression in this country concerning the difficulty of building destroyers, it should be especially noted that the builders of the *Truxtun*, *Whipple* and *Worden* had no previous experience whatever in this class of work. The first boat had a successful official trial after having had four preliminary builders' trials, one only being at speed, the other two boats having only two preliminary trials each, of which one was at speed on the measured mile. The trials were conducted with the builders' crew, and the most serious accident was a slightly crushed finger.

# METALLIC PACKINGS.—PRINCIPLES OF DESIGN ESSENTIAL FOR SUCCESSFUL DEVELOPMENT.

By Charles Longstreth, Associate.

## INTRODUCTORY.

Metallic packings attracted attention at a very early date in the history of the steam engine. Edmund Cartwright's patent of 1797, No. 2,202, specifies the following: "The piston rod is also packed upon the same principle, that is to say, solely with metal which is thus done: The top of the cylinder being made true and smooth, a flat ring, cut into segments, lies upon it and embraces the piston rod, towards which it is pressed inward by springs; this ring is enclosed by another, divided into segments, and to which it is pressed inward by springs. The segments of the inner and outer ring must be so placed as to break joint. The rings are covered by a third, which is held down by any adequate pressure, as in the piston; the whole may be encircled by a box for holding oil, etc." This covers the principal points of quite a number of the well-known packings of the segmental block type in use at the present time.

Also Richard Trevithick's patent of 1815, No. 3,922, particularly alluded to a combination of fibrous and metallic packings. He also describes a design that is practically the basic principle of the present double packings, that is, two stuffing boxes with intervening space. At that early date he was impressed with the friction caused by the fibrous packings, and used his double packing with the idea that he could overcome some of this friction by allowing steam or water to occupy the space between the two packings.

John Barton's patent of 1816, No. 4,062, and drawings which accompany it, plainly show a very ingenious segmental block

packing, which would probably be considered a good one even at the present day.

From what we read of these early English patents, it is quite surprising that metallic packings were not more generally used at an earlier date. The only reason given for their disuse was probably the imperfect condition of piston rods which would not permit the use of any form of metallic packing, owing to the irregularity of surface which became more noticeable on account of the long strokes then in use.

### PURPOSES AND REQUISITES OF A SATISFACTORY PACKING.

The purposes of a piston-rod or valve-stem packing are to prevent leakages of steam both along the rod or stem, and also between and around the packing, and to do this with minimum pressure and friction. At the same time the packing should not be designed to act as a guide for the rod or stem, thus partly usurping the function of the crosshead guide. The packing, on the contrary, should be designed so that it will be sufficiently flexible to follow slight lateral movement of the rod while remaining steamtight. It is to the satisfaction of this latter requisite that the more recent designs of metallic packing owe their superiority over the old-fashioned fibrous or the early designs of metallic packing. In this connection it will be well to refer to certain remarks on this same subject of rod packings found on pages 3 and 4, Vol. XIV of the JOURNAL.

### CHARACTER OF PACKING DEPENDENT UPON NATURE OF MOTION OF WORKING PARTS—WHETHER ROTARY OR RECIPROCATING.

In designing packing, we must consider the character of the rods or stems to be packed—that is, whether the moving parts have a rotary or reciprocating motion. If the moving parts require no guiding, as in the ordinary type of steam pumps, the problem is a comparatively simple one. If the moving part has a slight vibratory as well as a reciprocating motion, then the problem becomes quite difficult to solve. This vibratory motion, being caused by the slight difference in diameter between the piston and cylinder, as well as by the play between crosshead

and guide, changes at every point of the stroke and varies with every position of the connecting rod. Slight vibratory motion may also be caused by the roll or pitch of the vessel, in the case of marine engines, and while the amount of such motion may seem trivial to some, it bears a very important relation to to the wear of both packings and rods.

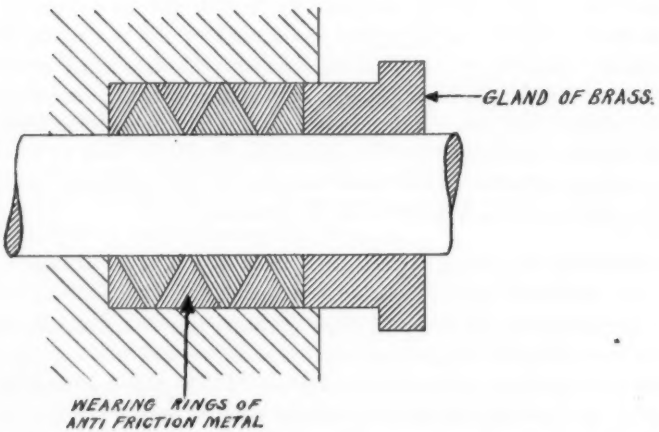
### CHARACTER OF PACKINGS—RIGID *VS.* FLEXIBLE.

In order properly to classify packings to meet the varying conditions to which they are subjected we should divide them into two general classes:

(*a.*) Rigid packings of the male and female-ring order.

(*b.*) Flexible packings, which can again be subdivided into two types—the segmental or block design and the conical-ring form.

FIG. A.




*Rigid Packings.*—This design is illustrated by cut A. It prevents the leakage of steam around the stuffing box, by having the outside of the female rings pressed against the stuffing-box wall. In order to prevent the leakage of steam along the rod,

the inside of the male rings is pressed toward the rod. The force holding these rings against the various surfaces is exerted by pressing the gland against the end of the rings. As ordinarily designed, it will be observed that the great trouble with such packings is to secure a steamtight joint against the wall of the stuffing box, as there is no wear there. This can only be accomplished by producing great friction and pressure against the rod, and as the packing fills the entire space between the walls of the stuffing box and the rod, it does not allow any of the vibratory motion previously alluded to.

Where vibratory motion exists and this class of packing is used, the packing is compelled to do a large amount of the guiding that should be taken up by the walls of the cylinder and the guides. The absurdity of attempting to do this part of the work with a surface so small and a material so soft as that of the packing will be at once apparent to the engineer. It can readily be seen why piston rods fitted with this type of packing require such an excessive amount of lubrication to prevent the rods from running hot. Frequently, with packings of this type, rods become so hot as to melt the anti-friction metal and cause it to run from the stuffing box. This packing, therefore, can only be used with success on valve stems and rods of auxiliaries, as well as on appurtenances to boilers and engines.

It is possible, however, to design this packing so that the amount of pressure against the rod may not only be reduced, but at the same time the leakage around the wall of the stuffing box may be stopped. It goes without saying that this packing may be used where the motion of the rod or stem is comparatively small or infrequent.

It is usual in most cases to place one turn of fibrous packing under the gland; often it is claimed that this turn of soft packing is for lubricating purposes, but as a matter of fact the manufacturer of the class of packings under consideration knows that it is really placed there to prevent the slight leakage of steam due to improper design of packing. Some properly-designed packings of this character may be used with a turn of soft packing while they are being broken in. After the metallic packing

has worn down to a bearing the soft turn may be removed, since the metallic packing will be found to be steamtight. Packings of this design are of very early origin, the first of them being used about 1843.

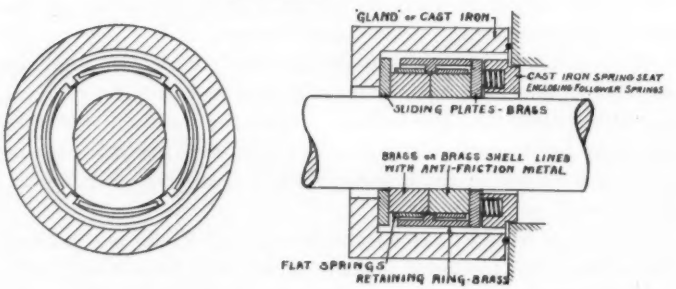
### FLEXIBLE PACKINGS.

The succeeding types of packings, which may be considered as designed on engineering principles, differ entirely from the foregoing. The new designs do not attempt to fill the entire stuffing box, as steam is allowed to enter the stuffing box and the packings thus have a chance freely to acquire a vibratory motion. The steam leakage around the walls of the stuffing box is duly taken care of by metal or other gaskets under glands, and by sliding faces ground steamtight. The gland is thus pulled up tightly against the intervening joint and the cylinder head, and all the adjustment takes place from the inside.

### SEGMENTAL RING OR BLOCK FORM OF PACKING.

The segmental ring or block form of flexible packing is shown by cut "B." These packings are usually metallic segments,

FIG. B.


GLAND or CAST IRON
CAST IRON SPRING SEAT ENCLOSING FOLLOWER SPRINGS
SLIDING PLATES - BRASS
BRASS or BRASS SHELL LINED WITH ANTI-FRICTION METAL
FLAT SPRINGS
RETAINING RING-BRASS

although it is often the case that they are simply blocks of metal held fairly close to the rod by some form of pressure—that is, either by means of a spring, by the pressure exerted by the steam, or by a combination of both these forces.

There are probably more different designs of this class of

packing than of any other, since such forms may be designed by people of comparatively little experience, and give fairly good satisfaction where moderate steam pressures are used.

Those in charge of marine machinery should be impressed with the fact that the quality of the steam supplied to the engines will have a very important influence upon the life of the packing. There is no doubt but that even a slight amount of water in suspension in the steam brings with it from the boiler some gritty substance. While this amount may be apparently of an inconsiderable nature, it is sufficient to greatly increase the wear of the packing.

The relative life of the packing when using both dry and saturated steam was evidenced in the case of engines of sister ships belonging to the same line, running on the same service and carrying the same pressures. On the high-pressure rod of one ship, where no care was taken to secure dry steam, the life of the packing averaged about thirty days' wear. On the engines of the sister ship, where care was taken to secure dry steam, the same packing has been in use for several years.

### OBJECTIONS TO THE USE OF SEGMENTAL PACKING.

The principal objection to segmental packings is that they are expensive to manufacture and necessitate care in maintenance. They are generally of a complicated nature, since they comprise a large number of springs, segments and rings. As the packing is forced to the rod by the steam pressure, the friction on the rod or stem increases proportionally with increase in boiler pressures. In other words, it is almost impossible to use packings of this character on a triple-expansion engine and obtain anywhere near the same length of wear from the packings for the three different cylinders; the high wearing out most rapidly, the intermediate wearing out next rapidly, and the low lasting the longest.

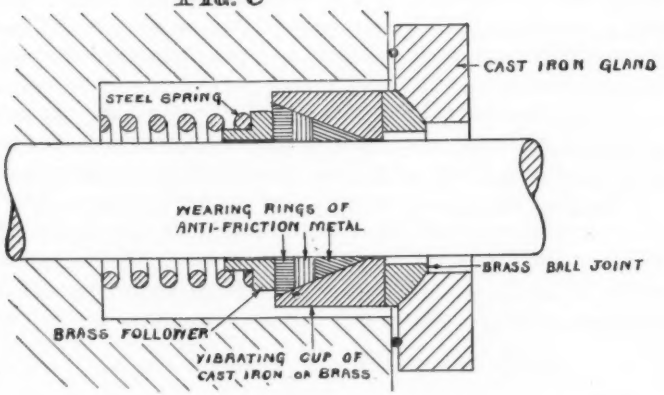
### FLEXIBLE PACKINGS—CONICAL-RING TYPE.

The last type of packing to be considered is usually known as the conical ring, and is shown by cut C. This type of packing has given better satisfaction under adverse conditions than all

others, and is the packing used on 90 per cent. of the locomotives running in the United States. This in itself is an evidence of its ability to run under adverse conditions with little repair.

The principle of this packing is that conical, soft-metal rings are pressed against the rod, and thus packing is accomplished by the rings being forced into a solid cup bored to conform to the

FIG. C




outside of the rings. These rings are pressed into the cup partly by a spring, but principally by the steam itself. If the pressure of steam was constantly on the packing the springs would be unnecessary, as the springs are used merely to hold the packing in place while steam is shut off the engine.

In order that this packing shall be satisfactory, the cup must not be allowed to touch the wall of the stuffing box at any time. The proper design as well as the character of material of these packings is therefore the most difficult ploblem to be solved in the packing business, as the mixture of metal in the rings, as well as the form of the outside of the rings, must be such that the packings will merely prevent the leakage of steam and not cause excessive friction.

Where properly designed, these packings can be made to give approximately the same length of wear on all the rods of a

multiple-expansion engine. However, in practice it has been found that this is not entirely desirable, and so, when usually designed by first-class manufacturers, the high-pressure packings wear out a little while before the intermediates and low.

It will be often noticed that the shape of rings in packings of this character on the high-pressure rods is slightly different from that on the intermediate and low.. In order to permit cheap and rapid repairs, it is desirable to have a uniform quality of metal used for the rings, while it is also necessary to have the form of rings balance differences in pressure.

### ADVANTAGES OF CONICAL-RING DESIGN OF PACKING.

With this type of packing there is absolutely nothing that comes in contact with the rod except the white-metal rings. The glands, neck bushings, cups, followers, etc., being bored considerably larger than the diameter of the rod or stem, and as the rings are made of soft metal and properly designed, they will cause very little friction and wear on rods.

Many experiments and tests have lately been made with packings of this nature, and where proper provisions are made to allow the rings and their enclosing cups to move freely with the rod they have been universally satisfactory. In order to allow the cup completely to accommodate itself to this condition, it is advisable to provide a ball joint in addition to the sliding face previously alluded to. A hot rod from packings of this type is practically unknown, and in railway service, where at the present time all details of this kind are apt to be carelessly handled, that they operate with any degree of success at all, speaks volumes for their design. In addition to the above, the advantages of this type are that wearing parts are inexpensive and easy to replace.

### DISADVANTAGES OF CONICAL-RING DESIGN.

The disadvantage of these packings, if it can be called a disadvantage, is that they will not work properly on a rod unless the rod is cylindrical. When packings are applied, if the rod is cylindrical, even though it is grooved, these packings in a short time will become steamtight. There are many cases on record

of extremely long service without renewals of this class of packing. Cases are on record of ten years' run, although the average life may be taken as from two to five years, and then the packings may be put in as good condition as they were when new, by merely supplying a few inexpensive soft-metal rings.

ENGINE EFFICIENCY GREATLY DEPENDENT UPON CHARACTER OF PACKINGS USED.

It is remarkable how little attention has been paid to this engineering subject and the ignorance of proper principles upon the part of engineers. It really requires very little cross-section of rings to do this work of packing, provided everything is properly designed; and the old notion, that the more rings and the deeper the stuffing box the better the packing, should be discarded as entirely wrong. If the packing manufacturer were consulted at the time engines were designed, it would often be possible on the ordinary marine engine to lower the cylinders from six to eight inches, and keep the other proportions of the engine exactly the same. From this can be readily seen the importance of this subject. Think of the weight of metal saved in six inches of housings, piston rods, valve stems, etc.

PROGRESSIVE INCREASE IN PISTON SPEEDS AND CYLINDER PRESSURES NECESSITATES THE USE OF HIGH-GRADE METALLIC PACKINGS.

Until late years, and at the time when steam pressures were low and piston speeds moderate, almost any kind of packing would give fair success, as on account of these low piston speeds and steam pressures the crossheads and guides would run very close, and pistons would usually fit cylinders much closer than would be possible under modern conditions.

It will frequently be noticed that many of the old types of packing which met with first-class success until a few years ago are giving much trouble on the more modern types of engines, with their increased piston speed and steam pressure, not only wearing out more rapidly but causing heating of rods, which is a proof of excessive friction.

Many new engines have been seriously injured on account of this improper design of packing. With packing of proper de-

sign it has been found that metals may be used for packing rings which melt at a temperature within 50 degrees Fahrenheit of the temperature of steam in the cylinder. This is direct evidence of the small amount of friction.

### IMPORTANCE OF CARE IN DESIGN, MANUFACTURE AND INSTALLATION.

To go into this matter fully would require quite a long paper. To get an idea of how much thought and care is required to design the last mentioned type of packing it should be borne in mind that the amount of curvature of ball joints bears quite an important relation to the wear of rings for different kinds of service. Also, as previously explained, the shape of the interior of cup and white-metal rings should vary to a certain extent with the steam pressure, and again the quality of metal used for the wearing rings requires deep study to meet the varying conditions. An instance of this can be seen in railroad service, where for years it was thought that nothing but a very expensive, high-grade babbitt metal would do for packing rings. After considerable experimental work had been done it was found that a metal costing one-quarter as much would not only prove more economical, so far as price was concerned, but would give much better service in the packing.

As superheated steam is slowly coming into use, the packing manufacturer must also follow and be able to take care of this question, and this requires a renewed study of the case and much experiment.

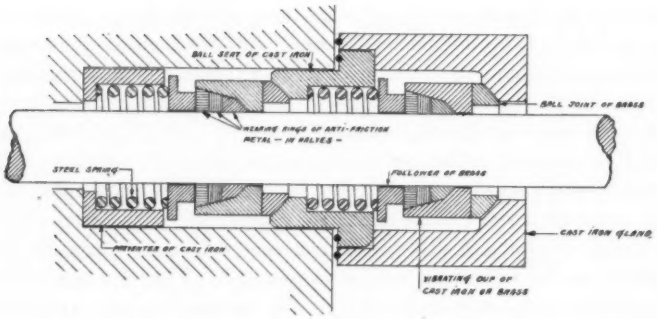
In practice, for most stationary and marine engine work, double packing is used, as shown by cut D, that is, practically two stuffing boxes, the packing nearest the cylinder doing all, or nearly all, of the real work. The lower packing does little or no work until the upper packing is worn out or fails or leaks, when the lower packing catches this leakage or takes up the work in case of failure.

### CAREFUL ATTENTION NECESSARY FOR EFFICIENT MAINTENANCE.

Regarding the care and maintenance of this class, we quote from instructions given by one of the well-known packing companies:

"The principle of this packing is a cone cup (known as vibrating cup) around rod or stem, into which are fitted the soft-metal rings. The soft-metal rings are held in vibrating cup by a spring, and the steam pressure forces them to make a tight fit around rod when engine is working.

*Fig. D.*


BALL SEAT OF CAST IRON
BALL JOINT OF BRASS
BEARING RINGS OF ANTI-FRICTION METAL — IN HALVES —
STEEL SPRING
FOLLOWER OF BRASS
CAST IRON GLAND
FOLLOWER OF CAST IRON
VIBRATING CUP OF CAST IRON OR BRASS

"The principle of operation of this packing is that the soft metals, after joints come together, are forced by spring and steam pressure into the vibrating cup; hence to the rod by a flow of the metal itself.

"The soft-packing metal rings which come in contact with the rod, and which do the actual work of packing, are cut in halves with a small open space between them when first applied, so that they may rapidly conform to the surface of the rod. When they have done this the open space between these rings will be closed up, ends coming solidly together, and in this condition rings are intended to wear, and will last four or five times longer than they would if continually cut so as to stand apart.

"One-sixteenth of an inch is all the space required between the ends of the packing rings when they are applied.

"If rings are continually cut apart at joints the wear on the rods will be large, and rings themselves will have an extreme tendency to force out between the opening of the vibrating cup

and rod. If these rings do not work properly when thus applied, and packings blow, there is something wrong, either with the mixture of the metal rings, the manufacture of the same, or the rod is taper or badly shouldered.

"In applying new rings, or investigating trouble with packing, see that joints of rings are 'broken.' Examine faces of ball joint and vibrating cup and see that they are clean. Often packing will leak, due to foreign matter between ground faces of gland, ball joint or vibrating cup. Vibrating cups should fit within $\frac{1}{64}$-inch of rods or stems. This will also prevent packing rings from being forced out between vibrating cup and rod, and will insure greater service of the rings. If absolutely necessary, soft packing may be used in the vibrating cups until rings are obtained, although it is far better to have spare sets of rings always on hand."

With double packings oil may be introduced into the lower stuffing box by means of a force pump. This oil when forced into the gland will entirely surround the rod, and the rod will then be running in a bath of oil. Should any leakage of water occur, it may be drained off and a little more oil introduced. By this means of lubrication swabbing of rods may be entirely dispensed with and a large amount of oil saved. In applying this method of lubrication it is well to be careful regarding low-pressure rods when working in connection with the condenser, in order to prevent oil from being drawn up through the packing into the cylinder.

In connection with low-pressure cylinders it should also be noted, in packings of the conical-ring type, that it is necessary to make the springs in this case sufficiently strong to counteract the tendency of the air to unseat the packings and enter the cylinder. This is the only case in which springs bear an important relation to packings of this type.

### CO-OPERATION OF MANUFACTURER AND USER ESSENTIAL TO PROGRESSIVE DEVELOPMENT.

The packing manufacturer, in addition to his usual troubles, is often handicapped because he does not hear enough of the suc-

cess or failure of his goods. If engineers assisted the packing manufacturer in this matter, stating the causes of trouble when it occurs, and working together with him in this way, I feel that much better results could be obtained than is the case at the present time. With multiple cylinders, high pressures and high piston speeds, this comparatively small part of the steam plant is growing rapidly in importance, and, although almost every engineer of note up to the present generation has patented, at some time in his life, a form of metallic packing, still hardly any of these are in use. There have been thousands of packings invented, but at the present time there are less than twenty-five recognized packings in the market.

### INJURIOUS EFFECT OF WATER UPON ALL FORMS OF PACKINGS.

One of the greatest enemies and causes of trouble to any first-class packing is water in cylinders, which, when it occurs, demoralizes the packing. Strange to say, no metallic packing has been designed which will give first-class results as a water packing—the water rods of pumps, for instance. When first applied they usually work with fair success, but soon commence to leak and continue doing so. Also no thoroughly satisfactory packing has been invented and used for expansion joints. There is quite a large field for investigation in this direction.

# SEAMLESS STEEL BOILER TUBES.—THEIR LIMITED ENDURANCE A MENACE TO NAVAL EFFICIENCY.

By Lieutenant Newton Mansfield, U. S. N., Member.

Steel boiler tubes are now manufactured of mild steel, and are of sufficient strength to withstand all steam pressures allowed under the rules of the Steamboat Inspection Service or Insurance Regulations. The material that enters into their construction is of such high character that tubes can be twisted, upset, beaded, expanded or bent in any desired shape without showing signs of weakness. Although the factor of safety of a boiler tube, as now designed and manufactured, is probably higher than that of any other part of the boiler, the tube is the first part, despite its superabundance of strength and ductility, to corrode to an extent sufficient to impair the efficiency as well as the operation of the boiler.

When lower pressures were used in naval boilers, and when there was no installation of electric power on board a warship, boiler tubes could be expected to last for several years. Under existing conditions there have been instances where tubes have commenced to give out within six months from the time the boilers were put to practical use. This weakness of boiler tubes is either due to corrosion or to the burning of the expanded ends, and such impairments are results either of defects of boiler design or construction, or else they arise from neglect or lack of knowledge in operating modern boilers.

Any design which does not provide for easy and free circulation of water will cause certain parts of the boiler at times to be subjected to excessive heat, and thus the character of such portions of the material is impaired. Muddy water will cause foaming, and thus impair the circulation in the tubes of certain

types of boilers. The use of an excessive amount of oil for the engines and auxiliaries will cause grease to be deposited upon the tubes, and, as such substances are not only poor conductors of heat, but upon decomposing injuriously affect metal surfaces, it is not surprising that the thin-walled tube is the weak link in the boiler chain. Lack of intelligence and skill in operation of boilers often injures them, and in the water-tube design of boiler it is the tube which receives the brunt of all these attacks.

### MARKED IMPROVEMENT IN DESIGN OF WATER-TUBE BOILERS DURING THE PAST FEW YEARS.

There has been such an improvement in the detail of design of water-tube boilers, that in nearly every type of steam generator a fairly good circulation can be secured under natural-draft conditions. It is when unusual conditions prevail, such as the use of muddy feed water, incompetence in the management of the boiler, use of heavy forced draft, bad firing and other causes, that the complicated or ill-designed type fails to give satisfaction. By reason of the more general knowledge now existing, however, concerning the principles of construction of water-tube boilers, the endurance of such steam generators is much greater, and therefore it is reasonable to presume that hereafter the life of the tubes will be much longer. With this advancement of knowledge as regards the principles of marine boiler construction, and with the progressive use of higher pressures, the boiler tube manufacturers have kept pace, and they have given the engineering world a more uniform and enduring tube.

However satisfactory the circulation, however fresh the feed water, and however intelligent and skilful the supervision, there is an unaccountable and rapid deterioration of boiler tubes that seriously interferes with naval efficiency. The boiler problem will always be an important one as long as the life of the tube is short, and as long as corrosion is unaccounted for. This is a subject worthy of investigation and experiment, and such research should be conducted under Government direction, for the naval and maritime interests of the country demand that

systematic and extended tests be conducted to determine the causes of this deterioration.

### THE CORROSION OF TUBES A MENACE TO NAVAL EFFICIENCY.

While the tubes should be, for reasons of safety and economy, the weakest part of the boiler, the Navy should not rest content with existing conditions as regards the endurance and life of the tubes. In every naval service the question is being asked—What induces this rapid corrosion? Is it due to high steam pressure, galvanic action between boiler and condenser, electrolysis resulting from excessive installations of electric appliances, decomposition of greases, repeated use of the same feed water, or fault in manufacture? If such corrosion could be prevented, the tubes could be made thinner, and thus a material gain made as regards lightness in boiler construction; the coal consumption could also be reduced, for a few leaky tubes will seriously impair boiler efficiency. The manufacturers of boiler tubes are making extended investigation to discover if the fault can be laid at their door. The extended research which they are conducting is more in the nature of manufacturing a tube that will better withstand corrosion than producing material which will have greater strength and ductility.

### ENDURANCE OF IRON AND MILD-STEEL TUBES AS REGARDS CORROSION.

The causes of corrosion of boiler tubes will never be definitely ascertained until the tubes are subjected to extended and numerous tests, under conditions approximating to those found when the boiler is in actual service. It is a matter of special importance to ascertain more definitely whether iron or steel of low carbon will best withstand corrosion. Upon this point, Dr. R. H. Thurston ("Manual on Boiler Design") states that boiler steel, a steel of low carbon, is better able to withstand corrosion than iron. This opinion, as to the comparative superiority of steel over iron to resist corrosion, is sustained by the results of the valuable experiments conducted upon this subject by Lieutenant Commanders Walter F. Worthington and W. H. Chambers. These two officers investigated the subject independently of

each other. The experiments conducted by them consisted of immersing specimens of charcoal iron, cold-drawn mild steel, hot-drawn mild steel, and lap-welded mild steel tubes to the action of distilled water through which air percolated.

The result of the experiments conducted by Lieutenant Commander Chambers gave the least rate of corrosion to the hot-drawn seamless steel tubes when absolutely free from millscale. The superiority, however, of the hot-drawn tubes was not very marked over the lap-weld and cold-drawn seamless steel ones. All the steel tubes withstood corrosion better than the iron. The experiments of Lieutenant Commander Worthington showed that no material with millscale upon it should enter into the construction of a marine boiler. This is a fact that tends to favor the use of cold-drawn seamless steel tubes as opposed to the hot-drawn product.

### THE VALUE OF NICKEL-STEEL TUBES FOR NAVAL PURPOSES.

It is well known that an alloy composed of mild steel and 30 per cent. to 35 per cent. nickel is practically incorrodible. Tubes of such an alloy have been used in France for torpedo boats and destroyers, and if the endurance of the tubes approaches anything like the promises made for them, then we can look for marked gain in boiler efficiency and endurance by the use of such material. Experiments are now being made in this country to determine the value of such tubes for marine purposes, and it is hoped that before the end of the year the manufacture of such tubes can be commercially undertaken. It is safe to say that if the manufacture of nickel-steel tubes can be successfully accomplished, it will not only increase naval efficiency, but it will effect as great a revolution in the manufacture of the tubes as occurred in the manufacture of armor plate when the Krupp process was introduced.

### IMPORTANCE OF POSSESSING A SMOOTH SURFACE FOR INTERIOR OF TUBES.

In the preliminary report submitted by the Liquid Fuel Board of the Navy as regards the condition of the tubes of the Hohen-

stein boiler, it is stated that "for about 30 degrees of arc at the bottom of the tube there was a channel free from deposit." This is taken as circumstantial evidence that there was good circulation. Further, it is reasonable to suppose that the circulation must have been improved from the interior possessing a smooth surface. Every designer of water-tube boilers now recognizes the fact that water circulation is of primary importance, and that such circulation will be seriously impeded if the water has to pass through tubes whose interior is rough. The necessity of securing a smooth surface for water tubes cannot, therefore, be over appreciated. This is another fact that should tend to favor the use of cold-drawn steel tubes as opposed to those made by the process of hot-drawing. In the manufacture of cold-drawn seamless steel tubes, smooth surfaces can be secured on both the exterior and interior surfaces. Since tubes of such manufacture hold no mill scale whatever their use should be particularly advantageous to the Navy.

### EXTENDED USE OF COLD-DRAWN STEEL TUBES FOR NAVAL PURPOSES.

In at least ninety vessels of our Navy cold-drawn steel tubes are or will be used. The manufacture of such character of tubes is of comparatively recent date, and therefore it is in the vessels which have been laid down or completed during the past five years where such tubes are mostly used. In retubing the boilers of the older ships cold-drawn seamless tubes are generally used. Of the ninety vessels wherein such tubes will be or have been used, fourteen are battleships built or building, and fifteen armored or protected cruisers. Practically nearly all the torpedo boats, all of the destroyers and many of the gunboats and other vessels have such tubes.

It will, therefore, be of interest to the many officers who will become chief engineers of these vessels, or who will be detailed for duty in the engine rooms, to secure a general knowledge of the manufacture of cold-drawn seamless steel tubes. All will be better able to study the boiler-tube question after securing a general idea of the physical qualities and chemical composition

of the metal, together with the treatment that such tubes receive in the process of manufacture.

### MATERIAL AND ITS COMPOSITION.

The material is mild, open-hearth, basic steel taken from the bottom half of the ingots and received at the tube mill in round bars of from three to four inches in diameter and from eight to ten feet long.

Average tensile strength, 52,400 pounds per square inch.

Average elastic limit, 30,400 pounds per square inch.

Average elongation, 25 per cent. in eight inches.

Average reduction of area, 56 per cent.

Approximate chemical composition: Carbon, .17 per cent.; manganese, .45 per cent.; sulphur, .025 per cent.; phosphorus, .01 per cent.

The manufacture of the tube is comparatively simple, yet of such a nature that none but the best product should finally reach the finished state. The process may be divided into two parts, viz:

1. The hot treatment.
2. The cold treatment.

### THE HOT TREATMENT.

The round bars of steel are heated to a cherry red in a closed gas furnace, and are sawed at this heat, by a circular saw, in length commensurate with the required length of the finished tube. These sawed lengths are not allowed to cool, but are immediately put into another closed gas furnace and heated to a light-yellow heat. This second heating is gradual, the time required being from twenty to forty minutes. The distillation of bituminous coal is used as the gas for heating. The "billets," as the sawed lengths are now called, are placed in the coldest part of the furnace and rolled from time to time in the hottest part, so that every part of the billet may have the same temperature. The billets upon reaching the required temperature are taken

out and delivered to the piercing mill, the principle of which is shown in Fig. 1.

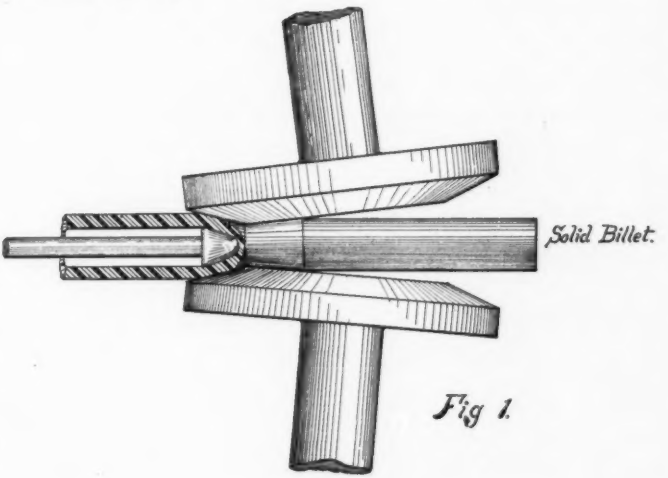



Fig 1.

THE PIERCING MILL.

The piercing mill consists of two discs of cast steel carried on the ends of two shafts whose center lines lie in the same horizontal plane, but slightly inclined to each other. The shafts revolve in opposite directions and make one hundred and twenty revolutions per minute. The faces of the discs may be brought nearer to each other or separated by adjusting screws to accommodate billets of different diameters.

The billet in its yellow-heat temperature is laid on a small guide between the faces of the discs so as to bring the axis of of the billet in the same horizontal plane in which the axes of the discs lie. The billet is then pushed by hand until its forward end takes against the revolving discs. The principle of the belt climbing to the high side of the pulley forces the billet on to the piercing point, which is shown in Fig. 1.

The piercing point pierces the billet while the beveled surfaces

of the disks roll the pierced billet out smoothly as it advances over the piercing point. The piercing point and its mandrel are firmly supported so that the piercing point enters the center of the billet. It is not held rigidly in place, however, but allowed to revolve with the billet. Its rear end is held in a swivel amply strong to take the thrust of the advancing billet. After each billet is pierced, the piercing point and its mandrel are dipped in cold water to lower their temperature. Both disks are constantly cooled by a stream of cold water. The piercing point is made of hardest steel. The piercing of a billet is a severe test of the homogeneousness of the material.

The range of temperature within which a billet must be pierced is very small. If the metal is too cold, the billet is sometimes torn or may stop the mill; or, if too hot, may be very rough and contain injurious spiral twists. If the temperature is just right and the billet is in every respect a good billet, it goes through the mill smoothly, coming out with a central longitudinal hole, fairly smooth on the inside and holding considerable millscale on its outside surface.

The billet is now about twice its original length. It is not allowed to cool, but is passed immediately through the rolls. The rolls are the ordinary cast-iron rolls used in steel mills, but as the tube is rolled it is made to slide over a mandrel, whose point is held between the rolls. Should the "tube," as it is now called, cool too much for rolling, it is placed in a convenient furnace to receive the proper heat, but this is not done except in very long tubes that cannot be rolled with the one heat of the piercing mill. The tube is given from four to eight passes through the rolls, care being taken that the tube is turned through about ninety degrees after each pass in order that the walls may be rolled of even thickness. The tube is now about four or five times the length of the original billet and has a wall of about one-quarter inch in excess of the required thickness in the finished tube, while the excess in diameter over the finished tube is about one-half inch. There is little or no millscale on the inside, but considerable on the outside. This ends the hot treatment.

## THE COLD TREATMENT.

The tube, coming from the rolls with a fairly smooth surface on the outside and a smoother surface on the inside, is allowed to cool to the temperature of the air. It is then pointed. This is done by heating one end of the tube for a length of about one foot and crushing from six to eight inches of this heated end in a pneumatic hammer, forming a point so that the end of the tube may be started through a die of smaller diameter than the tube. This die is shown in Fig. 2. This point serves as a gripping surface for the pliers which pull the tube through the die.

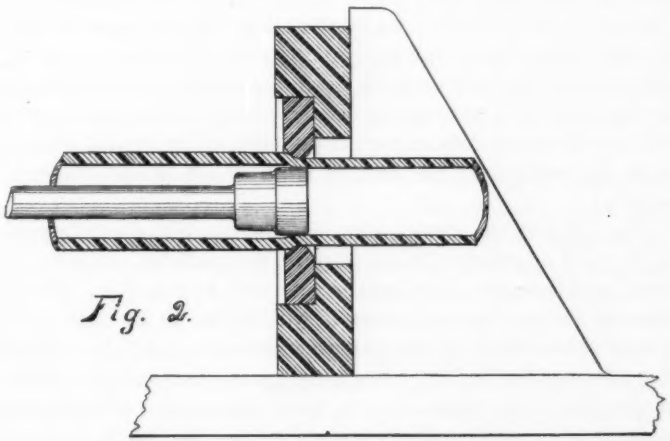


*Fig. 2.*

The tube, having been pointed, is taken to the pickling room and immersed in a hot, though weak, solution of sulphuric acid. This pickling removes the scale. After this immersion in the bath of hot sulphuric acid the tube is immersed in a bath of fresh water which washes away the loosened scale. The tube is then immersed in a mixture of tallow and paste, the paste being made of flour and hot water. This last operation, is called "dopeing." After "dopeing" the tube is dried for about five

minutes in a hot oven. The tube is now ready for the cold-draw bench room.

### THE COLD DRAWING.

The principle of the draw bench is shown in Fig. 2. The tube at its pointed end is closed, but the other end is open. Into the open end the mandrel is shoved until the mandrel takes against the pointed end on the inside of the tube. The mandrel is carried on one end of a long rod, the other end of which is secured to the draw bench to hold the mandrel in its proper position relative to the die. The pointed end of the tube with the mandrel on the inside is now passed into the die and the drawing pliers are made to grip the point. They work on the principle of ice tongs. Toes on the pliers engage in an endless sprocket chain which, traveling at the rate of ten feet a minute, slowly draws the tube through the die. The tube having passed through the die is reduced in diameter, reduced in thickness of wall and lengthened about twenty per cent. of its original length. Both the inside and the outside surfaces are smooth, almost polished.

The effect on the tube undergoing the process of cold drawing is good evidence of the quality of the material. If the material be of meager ductility the tube will tear in two. If the material be not homegeneous it will show in the surface as spongy spots, checks or small transverse tears. It will be noticed that the mandrel in Fig. 2 has no support other than the metal of the tube. By reason of this, hard spots easily displace the mandrel in drawing, which shows up on the inside surface. The tube is always drawn beyond its elastic limit. After the tube has made one pass on the cold-draw bench it is annealed in an open furnace which uses the distillation of bituminous coal as a source of heat. The temperature of annealing is that of cherry red, but may be so regulated as to affect the ductility and tensile strength within certain well known limits. The tube having reached the required temperature is taken from the oven and allowed to cool in the air, after which it is again pickled and immersed in the mixture of "dope" and dried. It is now ready for a second pass on the cold-draw bench.

NUMBER OF PASSES.

The number of times a tube is drawn on the cold-draw bench depends on (1) the thickness of the wall of the finished tube, (2) the tensile strength of the material of the tube, (3) the tensile strength of the rod holding the mandrel in its relative position to the die.

It is seen that in the cold drawing the pliers tend to pull the tube apart at the die, causing a tensile stress at the die which must be resisted by the tensile strength of the material in the tube. The ability of tubes to resist this tensile stress is manifestly greater in tubes of thick than thin wall, considering the area of the cross section of the tubes as resisting surface. It must not be forgotten that, as the tube is drawn through the die, and the metal is "sunk" around the mandrel, the friction between the inside of the tube and the mandrel tends to pull the mandrel through the die. This is resisted by the tensile strength of the mandrel rod.

In reducing a tube from a larger to a smaller diameter and from a thicker to a thinner wall, it must be borne in mind that required reduction must not be obtained by a pull equal to the tensile strength of the tube; and, further, the friction between the inside of the tube and the mandrel must be less than the elastic limit of the mandrel rod. If these two conditions are fulfilled the tube may be drawn safely through the die.

Large tubes of thick wall, therefore, do not require so many passes on the draw bench as tubes of smaller diameter and thinner wall. For instance, the 2-inch, 8 B.W.G. that are now being manufactured for the boilers of our ships receive but two passes on the cold-draw bench. In the first pass the diameter is reduced from $2\frac{1}{2}$ inches to $2\frac{3}{16}$ inches, while the wall is reduced from $\frac{5}{16}$ (.3125) inch to $\frac{7}{32}$ (.21875) inch. The second pass further reduces the diameter from $2\frac{3}{16}$ inches to 2 inches, and the wall from $\frac{7}{32}$ (.21875) to 8 B.W.G., or .165 inch.

A tube of 1 inch diameter and 11 B.W.G., as is used in the boilers of our torpedo boats, requires at least five passes. The reductions of diameter are from $1\frac{1}{2}$ to $1\frac{3}{8}$, $1\frac{1}{4}$, $1\frac{3}{16}$, $1\frac{1}{8}$, and 1 inch respectively, while the five passes reduce the thickness of

the wall at the same time to the following dimensions, viz: from $\frac{1}{4}$ (.25) to $\frac{7}{32}$ (.21875), $\frac{3}{16}$ (.1875), $\frac{11}{64}$ (.171875), $\frac{5}{32}$ (.15625), and 11 B.W.G. (.120) inch.

Both inside and outside surfaces are improved after each drawing. Before each drawing, however, the tube must be annealed and pickled. It is a question whether the improvement in the surface caused by a large number of passes on the draw bench compensates for the bad effects of annealing and pickling an equal number of times. The writer knows of no tests that have been made to determine this question. A smooth surface is certainly more desirable than a rough one for water-tube boilers. If care is used in the several annealings and picklings it is probable that the tube which has received the larger number of passes on the cold-draw bench will be the one better adapted to withstand corrosion in a water-tube boiler.

### STRAIGHTENING.

After the final pass on the cold-draw bench the tube is straightened cold. This is done by supporting the tube on two rollers, whose axes are about four feet apart. The tube may be moved in a horizontal direction over these rollers from one end to the other. A die working vertically midway between these rollers descends just far enough to make the tube lie in a straight line between one roller, the die and the other roller. The tube is constantly moved back and forth by hand, the eye of the man handling the tube sighting along the tube until it is perfectly straight. After straightening, the ends of the tubes are cut off to give the required length. The tube is then ready for inspection.

### THE INSPECTION.

The tube having thus far passed through the various processes of manufacture, and having satisfied the constant inspection that it receives while being handled cold by so many different persons, may not yet satisfy the requirements of the specifications. It must be remembered that the inside, the water side in water-tube boilers, has not yet been observed. The inside is more important than the outside, for its condition is a most important

factor in the problem of circulation. The tube should be absolutely smooth on its inside surface.

It has been the experience of the writer, in the inspection of cold-drawn seamless steel tubes, to notice the excellent inside surface of some of the tubes. Some of the best have a surface not unlike the polished inside surface of the barrel of a breech-loading shot gun. All the tubes presented for inspection do not have such a perfect surface, but have the otherwise perfect surface marred by a few small longitudinal scratches caused by small particles of scale or dirt lodging on the mandrel in drawing. If the scratches are few in number and of small depth and the remainder of the inside surface smooth, the tube is accepted so far as the inside surface is concerned.

The tube is also gauged at both ends for thickness of wall. An allowance of half a gauge is made for tubes of 9 B.W.G. or thicker. Tubes of thinner wall than 9 B.W.G. must be up to gauge. The outside surface, owing to its constant observation in the course of manufacture, is generally in good condition, having a smooth and almost polished surface. A few rejections are caused by marks in the surface, probably made by the disks of the piercing mill. After the tube has satisfied these requirements it is subjected to an internal cold hydraulic pressure of 1,000 pounds per square inch. This pressure could be much exceeded without bursting the tube. A tube of 12 B.W.G. and 1¼ inches in diameter was burst by internal pressure, but not until the gauge read 4,788 pounds per square inch.

### RETORT ANNEALING.

After the hydraulic test the tube is finally annealed in a closed retort. The retort is only a larger iron tube 14 inches in diameter, the ends closed by cast-iron headers. The retort is loaded with the tubes and test pieces, two test pieces being placed in each retort in the center of the lot of tubes. The ends of the retort are then closed with the cast-iron headers. The closed retort is then run into the furnace on a car, then rolled off the car on the furnace floor. It is now rolled over about ninety degrees every twenty minutes, finally being rolled to the other

end of the furnace, having during this operation reached a light cherry red, and having soaked in this temperature (1,300 degrees Fahrenheit) for about two hours. At the further end of the furnace the retort rolls on another car which carries it out of the furnace. It is then rolled on skids, with other hot retorts, and the whole lot allowed to cool in the temperature of the air. The retort is not opened until the tubes are cool enough to be handled by the bare hand. This insures a slow and even cooling.

The test pieces which were placed in the retort with the tubes are taken out and given the following tests. One piece is placed under a steam hammer, axis horizontal, the hammer descends, smashing the sides flat together. The "Specifications" do not require so severe a test, but "the tube shall be flattened down so that the sides are brought parallel with a curve on the inside at the ends not greater than three times the thickness of the metal without showing cracks or flaws."

The writer has never had a failure of a test piece either by flattening down, as required by the specifications, or by smashing the test piece flat together under the steam hammer. The other test piece is placed under the steam hammer, axis vertical, a taper plug, six inches to the foot, is inserted in the test piece and driven down until the tube end is one and one-half its original diameter. This is also more severe than the test required by the "Specifications," which require a taper plug with a taper of 1½ inches to the foot to be driven into the test piece until its diameter is increased 12½ per cent.

A third test piece is placed under the steam hammer, axis vertical, the taper plug being driven into it until its diameter has been increased one-fourth, the taper plug then being removed and the test piece struck with the hammer until the taper part is turned out at right angles to the axis, forming a flange of a width equal to 37½ per cent. of the original diameter of the tube. The "Specifications" require the flange to be of a width of but 12½ per cent. of the original diameter of the tube. The writer has never witnessed a failure of a single test piece tested as here described. These tests are all made cold.

The tube having satisfied these tests and inspections, may now

be finally accepted, and, before shipping, is immersed in a bath of boiled linseed oil to preserve the surface from any corrosion that might occur in the time between the shipping from the mill and the installation of the tube in the boiler. Before the tube is installed in the boiler the coating of linseed oil is removed.

Tubes made as here described will be installed in all the boilers of our new battleships and cruisers. As many as 15,149 tubes are to be placed in the boilers of a single ship, aggregating 123,712 pounds. Each tube must be inspected inside and outside and gauged at both ends.

In conclusion, the cold-drawn seamless-steel tube, from its method of manufacture, insures

1. Absolute homogeneousness of material.

2. Smooth surfaces, which, in a boiler of good circulation, will tend to prevent the deposition of scale.

3. A homogeneous surface which should tend to distribute the corrosion evenly over the entire surface.

4. Physical strength far beyond that required.

If hot-drawn tubes corrode at a less rate than cold-drawn tubes, the material being the same, a factor in the rate of corrosion may lie in the method of cold handling. It will be an interesting experiment to subject specimens of cold-drawn tubes of the same material, but which have been drawn under different values of tensile stress on the draw bench, to the influence of corrosion, in order to determine at what stress the material may be drawn cold to give the mimimum rate of corrosion in the finished piece.

## PROBABILITY OF SOLVING THE BOILER-TUBE PROBLEM AT THE PROPOSED NAVAL ENGINEERING LABORATORY.

The manufacturers of boiler tubes are taking a special interest in the establishment of the Naval Engineering Laboratory that was authorized by the Fifty-seventh Congress. These business men fully appreciate the fact that when the staff of the laboratory takes up this question of the deterioration of boiler tubes, that it will be possible, with naval resources, to conduct experiments that could not be undertaken by private firms. They likewise

stand ready to unite with the naval authorities in trying to find the solution of this problem. They will not only supply material, but, if necessary, will manufacture specimens containing such ingredients as the staff of the college may deem necessary, whereby tests may be conducted which will result in giving increased endurance to the tube.

It has been very unfortunate that heretofore there has been no central experimental station in operation where all manufacturers could meet on a common ground. If such a plant had been in existence greater success would have been met heretofore in the solution of the problem. The projected station at Annapolis offers just such a field, and, as stated by the Engineer in Chief of the Navy in his annual report: "It will well repay the country in the outlay for an experimental station if the staff of the laboratory will cause increased endurance to the life of boiler and condenser tubes."

There is no doubt but that when the laboratory staff works in conjunction with the boiler manufacturer, the problem will be simplified, if not solved, of giving to the naval service a tube whose endurance can be depended upon for years rather than months.

# MANEUVERING QUALITIES OF BATTLESHIPS.

## IN-TURNING *VS.* OUT-TURNING SCREWS.

[Reprinted from "Army and Navy Journal" of April 25, 1903.]

---

The great importance of the discussion throughout the naval service as to the relative values of the out-turning and in-turning screws for battleships has led us to request Rear Admiral George W. Melville, Chief of the Bureau of Steam Engineering, to furnish the "Army and Navy Journal" with his views on the subject. The matter has not yet been definitely settled by the Board on Construction, and without doubt this expression of the Engineer-in-chief of the Navy will be read with exceeding interest by all interested in the discussion. It is a very thoughtful and conservative expression of opinion, and the advocates of the out-turning system will be forced to bring some substantial facts to controvert the argument advanced.

Admiral Melville's views are as follows:

"The question as to whether the screw propellers of warships should turn inboard or outboard is not new to the engineering world. For twenty years the subject has been discussed, the controversy starting anew every dozen years by reason of some naval expert bringing up a new phase of the question. The principal point at issue for many years was that of propulsive efficiency. Both experiment and experience showed that if there was any advantage of either installation, it leaned towards that of the design which turned inboard. This was absolutely independent of any engineering reasons for having the screws turn in that direction.

"The question as to which form of installation gives the best maneuvering power has been touched upon several times during the past twenty years. There is no information extant, that for

deep-draught vessels, there is any resulting maneuvering advantage for either form of installation. It was because there were important engineering reasons for turning the propellers inboard, and no apparent advantage in having them work outboard, that naval engineers rather inclined to the inboard system of working screws."

THE OPINION OF BRITISH NAVAL EXPERTS.

About a year ago Admiral Sir J. O. Hopkins, K. C. B., read a paper before the United Service Institution of Great Britain concerning the advisability of building smaller battleships. One of the points that he brought up was the following:

"*Should the propellers in future designs of battleships turn inwards or outwards?*"

Admiral Hopkins touched very beiefly upon this special point —that point being one of a half dozen which he presented for special discussion. The remarks of Admiral Hopkins concerning in-turning *vs.* out-turning screws are as follows:

"My own experience of two ships in the Mediterranean is against the screws turning inward, as it handicapped the ships turning with no 'way on' to such an extent as almost to make turning on their heels without 'way on' impossible. And many of you will call to mind, with the outward revolving propellers, how the good ship under you steadily swung round the compass without moving ahead or astern by simply revolving the screws in opposite directions, and one always felt what a pull it was in close harbors or tight places."

"The good ships of the past," of which Admiral Hopkins speaks as being so readily maneuvered, were of broad beam as compared with their length, and were therefore much easier handled than their prototypes of today. The merchant steamers of the same period were handled with ease, and steamed rapidly into harbor, while the larger passenger steamers of the present day are brought slowly into port. It is thus fair to presume that it is by reason of the increase in displacement and in ratio of length to beam that the maneuvering quality of the battleship has been sacrificed, and not because of an installation of in-turning screws.

### VIEWS OF ADMIRAL SIR N. BOWDEN-SMITH, K. C. B.

In the discussion of Admiral Hopkins' paper, Admiral Sir N. Bowden-Smith, K. C. B., stated as regards the inboard-turning screw question:

"The lecturer asked whether the screws should turn outwards or inwards. If by their turning inwards the ship cannot be turned so readily with no way on, I would not sacrifice the ship's turning power for a slight increase in speed."

### ADMIRAL BERESFORD FAVORS OUT-TURNING PROPELLERS.

Rear Admiral the Right Hon. Lord Charles Beresford, C. B., made this statement in answering Sir John Hopkins' question as to the direction in which the screws should be turned:

"The next point is with regard to the inward screw. I entirely agree with Sir John Hopkins. The inward screw does militate against the handiness of the ship when going in and out of harbor on ordinary active service; and it is a hundred chances to one in an action that a skilful captain who knew his ship absolutely might sink an adversary or might avoid being sunk if he had outward-turning screws. Probably the inward-turning screws do produce a little extra speed. The real reason for the inward-turning screw was to give the engineer a little better control over his engines. That is a very good point, and a very serious point; but everything to do with the ship is a compromise, and you most certainly ought never to sacrifice the fighting efficiency so that the captain is unable to do his level best with the ship under any consideration whatever."

The paper of Admiral Hopkins was discussed by Vice Admiral C. C. P. Fitzgerald, the Right Hon. Lord Brassey, K. C. B., and Admiral the Right Hon. Sir J. C. Dalrymple Hay, K. C. B., but none of these three distinguished experts gave any consideration to the special point as to the relative advantages of in-turning or out-turning screws.

### ADMIRAL PARR FAVORS IN-TURNING SCREWS.

The subject seemed to appeal very strongly to Rear Admiral A. C. Parr, for he said:

"With regard to the turning power of the vessel with the screws turning inwards, I have often heard it said that the vessels do not turn as well as with those turning outwards; and having been recently in a position to make certain trials with regard to it, I thought it was advisable to do so. I did not find, with my own experience of outward turning screws, that the vessel always turned quite as easily as would seem to be indicated by the paper.

"The first vessel that I made experiments with was the new Royal yacht. I may say that with her there was no difficulty in going in and out of harbor—taking her into Plymouth Sound, picking up buoys, slipping from buoys, and taking her out again. But I thought it advisable to try her, so we put buoys down alongside the ship; she was stopped dead, and then turned through 90 degrees one way. After she was stopped dead we turned her through 90 degrees the other way, and there was not the smallest difficulty of any sort or description. She went smoothly and quietly, and never held up at all. That was in calm weather.

"The next ship I tried was the *Glory*. On that occasion there was a fresh breeze blowing—nearly 4, I should think—so much that I doubted whether she would have turned at all, even with outward-turning screws, and never expected her to do so with the inward-turning ones. However, she exceeded my expectations. When she was with the wind abeam, and stopped dead, with the engines working with a speed of about 12 knots ahead and astern, she turned slowly, but she turned steadily, and never stopped though she hung a little at times. She completed the 90 degrees up to the wind in, I think, something over a quarter of an hour. Of course that was a long time, but she did it, and she did it without much trouble. In turning the other way, when falling off, she did it in very much quicker time. The *Aboukir*, I think, was also tried with similar results."

ADMIRAL FREEMANTLE BELIEVES THERE IS BUT LITTLE DIFFERENCE.

Upon this special point Admiral the Hon. Sir E. R. Freemantle, G. C. B., thus spoke:

"As a little further criticism of the lecture, I should like to

allude to the question of the screws turning inwards. My experience is very much the same as that of Admiral Parr. I do not think there is a very great deal of difference in screws turning inwards or outwards. Where the difficulty comes in is where there is a breeze of wind or a nasty current on the bow—a nasty tide. Under those circumstances a ship, whether with screws turning inwards or turning outwards, will not generally turn without way on. There is a difference, I admit; but it is not so very great. The reason given by Lord Charles Beresford, why the screws turn inwards, is a very important one, namely, that the engineers may be able to control the engines with much greater facility at starting and stopping, and on every other occasion."

A careful analysis of the discussions of Admiral Hopkins' paper will show that as a matter of fact only one of the experts who took part in the discussion had attempted by practical experiment to secure positive information upon the subject. That officer was Rear Admiral Parr, and he favored in-turning screws.

*Admiral Hopkins asserts that the question was raised to invite discussion.*

One has only to read the reply of Sir John Hopkins to his various critics to show how he weakened upon his own proposition when confronted with the positive evidence furnished by Admiral Parr from careful experiments. In justice to Admiral Hopkins it is but fair to state that he did not unqualifiedly assert that in-turning screws impaired the maneuvering power of battleships. His contention was that he had found ships with in-turning screws difficult to maneuver, and that he invited expression of opinion from experts in the British Navy upon this question. In closing the discussion, Admiral Hopkins said:

"I am happy to think that in replying I have very little to say. I introduced my bantling to this distinguished audience in the hope that it would be very carefully nursed, so that we might see what sort of young man, or middle-aged man, or older man it might grow up into. A great many of the audience have been against the baby and have said, 'It is no use; cast it away.' Others have taken very kindly to it, and think it is worth a little

further nursing. The whole point was a matter for discussion, and I think out of that discussion we have heard very many valuable observations. Taking the last criticism first, Admiral Parr told us that he has found that the screws turning inwards produce as good results as those turning outwards from a dead point. My experience is totally different from that. My experience is, that with no way on there is no turning power in the ship that has her propellers revolving inwards. If he has proved otherwise, the service will be glad to know it as a fact, but hitherto we have usually heard the opposite. It is, however, a great comfort to hear the contrary. It was with a sad feeling that I saw all new ships, without exception, being fitted with the in-turning screws. If we come to the history of the in-turning screws, it is owing to the constructors, who go in for everything that will give them a trifle more speed. They do not think of it as the naval officer does, that is, how it affects everything. With regard to the chief engineer and the middle platform, that is a good thing, but it is not everything. Lord Charles Beresford was quite correct there. If you sacrifice to the smallest extent the turning powers of your ships, at any speed whatever, you are probably paying dear for it."

Since the discussion took place before the United Service Institution, quite a number of naval architects, marine engineers and naval tacticians and strategists have given expression to their views upon the subject.

*Vessels of heavy tonnage, whether battleships or ocean greyhounds, must be brought into port under reduced speed.*

One of the new reasons advanced for reverting to out-turning screws is the fact that it now takes a much longer time for the modern battleship to enter port than it did a dozen years ago, and the fault is ascribed to the installation of in-turning screws. It should be remembered, however, that the battleships have increased 50 per cent. in tonnage during the past decade, and that it is much more reasonable to ascribe the cause of requiring longer time to enter and leave port to the size of the ship rather than to the method of turning the propellers. The following

facts bearing upon this point should also be kept in mind: That most commanding officers possess but little experience in maneuvering ships of great size, and that those responsible for the safety of such vessels realize the imperative necessity of steaming such ships slowly into harbor. Whether the ship had in-turning or out-turning screws, disastrous consequences would eventually ensue if a vessel of 15,000 tons displacement was moved quickly to or from her dock, or speeded when entering or leaving harbor.

*The experience of the Cedric compared with the Cymric.*

In regard to the handiness of the great ocean liners, it may be pertinent to state that it is common report that the White Star Line Steamship Company has not found the *Cedric* a paying investment as compared with the smaller ship *Cymric*, of the same line. The *Cedric* has a length over all of 750 feet, an extreme breadth of 75 feet, and a gross registered tonnage of 21,000 tons. As she has to wait for the tide before entering or leaving port, and as she has to use tugs and be subjected to other delays, by reason of her size, it has been found that the financial return which was expected of the *Cedric* has not been secured, and that the primary reason is due to the question of delay at the terminal points. This vessel has out-turning screws, and, like all of her class, has to approach her wharf or anchorage very slowly.

*Ocean liners require aid of tugs to reach their wharves.*

It would be pertinent to remind those who are advocating out-turning screws that practically all the great ocean liners have their screws fitted in such manner, and yet when leaving or making dock such vessels invariably require the aid of tugs, and also enter and leave port at reduced speed.

It not only takes increased time for such large ships to enter and leave port, but it has been found that it requires increased time to learn to handle such vessels. Probably not one in every twenty officers of any navy has ever served in a battleship of 16,000 tons displacement, and it would be inviting disaster upon the part of any commanding officer who would not enter and leave harbor slowly when first taking command of a warship of that character.

*Imperative necessity of securing definite information upon the subject.*

If an installation of in-turning screws does impair the maneuvering efficiency of modern battleships, then the quicker the fact is discovered the better it will be for naval prestige and strength. It may be that a right conclusion has been reached in demanding a change in the direction of operating the propellers, but the reasons advanced for maintaining this opinion are not very convincing. The stake that is at issue is of such importance that our Navy could well afford to dock a battleship, and make a substitution of screws whereby the propellers that turn inboard will move outboard. The performance of a battleship fitted with such an installation of propellers could then have her work compared with a sister ship fitted with in-turning screws. This experiment would secure positive data upon the subject, and results rather than opinions would be obtained.

*Elements that will influence maneuvering quality of ships.*

There are many elements that will have an influence on the maneuvering qualities of the ship, such as the strength of the wind, character of the tide, the skill of the helmsman, draught, length, beam, displacement, distance apart of the screws, and speed of the ship. The personal factor may be the most important of all. A conclusion that is based only upon the value of one of several factors that produce a result cannot be regarded as reliable.

In our service the question has also been raised. The subject was again made prominent during the Caribbean maneuvers because one of the torpedo boats could not get away from the dock as easily as was expected. It mattered not that this particular boat possessed a high bow, and that the influence of the wind might have been a controlling factor. It is pertinent to call attention to the fact that one of the largest of the Herreshoff torpedo boats, which also has a high bow, but which has out-turning screws, likewise possesses poor maneuvering qualities.

*Systematic experiments have not yet been conducted.*

There is no evidence that any continued series of systematic experiments were conducted during the Caribbean maneuvers to

secure information upon this point. If such experiments had been made the Bureau of Steam Engineering would undoubtedly have been furnished with such information, for only three months ago contracts for two armored cruisers were given out, and surely the Department would have been put in possession of any definite information that had been secured by careful experiment.

It would seem that tactical and strategic reasons would prompt our naval authorities to secure comparative data as to the value of in-turning or out-turning screws, particularly as experiments of this character would give excellent opportunity to all deck officers to secure valuable information in the school of the ship.

*Positive information can be secured by conducting comparative tests.*

While engineering reasons would suggest that two large battleships should be used for conducting experiments along this line, there may be reasons of national policy why ships of such size should not be used for experimental work. I am at a loss to see, however, why the second-class battleship *Texas* should not be used for conducting such tests. It is a most important question that is at issue, and the solution of the problem is worthy the attention of naval tacticians and strategists. It should not require an expenditure of over $20,000 to make the tests and thus obtain absolutely reliable information upon the question at issue. Such experiments are absolutely necessary to secure naval efficiency. In time of peace the ships could not be put to better work than to subject them to experimental tests which would not only secure valuable data to the naval architect and the marine engine designer, but make the several deck officers thoroughly familiar with handling ships fitted with in-turning and out-turning screws. As soon as national policy would permit, sufficient vessels ought to be assigned to the solution of the problem, and there should be placed at the disposal of a special board at least two light battleships of the longest possible length as compared to beam and deepest draught, two sister cruisers of comparatively light draught, and two torpedo boats or destroyers of shallow draught. One vessel of each type should then be fitted with in-turning screws and its prototype with out-turning screws.

The vessels of each class should then be subjected to similar tests.

*Experiments should be of an extended nature.*

There should be no haste exercised in the attempt to secure data. As the question is an important one, the experiments should continue over a considerable period, for it must be remembered that the result will be affected by the tide, draught, force and direction of the wind, beam, displacement, distance apart of the screws and arrangement of machinery. It might even be advisable to have special experts supervise the maneuvering of the ships during the experimental tests, for the personal factor may be the most important one of all. It would be a waste of time and energy to take a torpedo boat with shallow draught and expect that experiments with that type of craft would solve the problem for the battleship. By securing comparative data derived from vessels of various tonnages experts would reach the right conclusion, for the results obtained would be founded upon facts and not upon fancies.

*Character of data that would be secured by comparative experiment.*

A series of such experiments would show that as the ratio of length of the ship to distance apart of the screws has progressively increased, the turning moment of the propellers is correspondingly less efficient, whether the vessel be fitted with in-turning or out-turning screws. It is because this ratio is excessive that even in the case of ocean greyhounds, vessels which are fitted with out-turning screws, that tugs must be used to bring these vessels to and from a wharf.

There has been very little positive evidence submitted, but considerable personal opinion expressed, as to the increased efficiency that might be expected as regards maneuvering power with ships fitted with out-turning screws.

*Diagrams applicable to special and unimportant conditions should be given little weight.*

Some diagrams have been made showing the relative effect of in-turning and out-turning screws. One set of these diagrams

shows the maneuvering effect of twin screws under engines alone, helm amidship, but with no steerage way, on light-draught ships. Such testimony can hardly afford much light on the question, since the case must be rare indeed when any commander of a warship would attempt to maneuver his vessel without the ship having some steerage way. When battleships are at a dock or in a slip there are invariably tugs available. It would be poor economy to fail to call upon at least one tug for assistance in departing from or approaching a naval dock when such tugs can be secured without expense. Conclusions drawn from such diagrams are of doubtful value, as the action of the propeller is so seriously influenced by its location as regards hull and its depth of immersion. The conditions which such diagrams illustrate do not approximate to what would occur in actual service and to deep-draught vessels, and are only applicable to special ships under special circumstances.

*Vessels with poorly designed rudders afford but little information.*

The experience of a ship fitted with an unusual design of rudder has been cited as illustrating the poor maneuvering quality of in-turning screws. Any vessel with an inefficient rudder can not be taken as a fair illustration of the worth of either in-turning or out-turning installations. If the screws of such a vessel were shifted it is possible that some reliable comparative data could be secured, but conclusions are worthless as to maneuvering powers when derived from any ship installed with an ill-designed rudder.

*Torpedo-boat destroyer conditions are not applicable to vessels of deep draught.*

The experience of some of the torpedo boats has been cited as illustrating the lack of maneuvering qualities of in-turning screws. So much depends upon the skill of individual commanders in handling torpedo boats and destroyers, and the conditions under which such vessels are operated are so varying, that any information upon the subject derived from this class of boats should not be regarded as conclusive unless comparative tests were made with similar boats fitted with different systems of turning the propellers.

*Naval engineers desire that comparative tests be conducted.*

While the British ships lately authorized have out-turning screws, I have learned from reliable sources that very little hope is entertained that any improvement will be effected as regards maneuvering power in the deep-draught battleships. The Bureau of Steam Engineering has likewise directed that some of the battleships lately contracted for should have out-turning screws, but such action has been based upon the hope that such installations will permit comparative information to be secured. Engineering efficiency, however, has been decreased to some extent by this action by decreasing the ability of those in the engine room to observe the working of certain parts of the machinery of both engines from the central platform.

*Experiments with yacht Niagara.*

The experience of the yacht *Niagara*, built by the Harlan & Hollingsworth Company, Wilmington, Del., is quoted as sustaining the contention that out-turning screws give greater maneuvering power than in-turning screws. The engineers of that company inform me that no experiments were made with the *Niagara* for determining the comparative maneuvering qualities of an in-turning and out-turning installation of propellers. The change of propellers was made simply to secure increased speed. While increased speed was secured by changing the screws to an out-turning direction, that was not the primary cause for the gain in speed. This increased propulsive efficiency was probably secured because there was considerable tuning up of the engines. The pitch of the blades had also been increased, and this may have had much to do with the results secured.

It is common every-day experience for steamship and yacht builders to change the pitch of the propellers, to tune up the engines and to make minor changes and improvements to attain the speed guaranteed. It is because the increased propulsive efficiency that was secured in the case of the *Niagara* was so much at variance with the results obtained elsewhere that I made special inquiry in regard to the matter, and found that the gain in speed was primarily due to changes and improvements that

would suggest themselves to any skilful marine engineer of experience.

*Bureau of Steam Engineering receptive for information upon question.*

The Bureau of Steam Engineering is exceedingly receptive for information upon this subject. The problem as to which direction the screw should turn has been under discussion for many years, and the weight of evidence is in favor of the propellers turning inboard. The question is too important to be decided by evidence or opinion that is not founded upon extended experience or experiment. It is possible for the Department to solve the problem very quickly, and that is by using pairs of good-sized ships to secure comparative data, one of each pair being fitted with in-turning and the other with out-turning screws.

The Bureau, however, doubts that the direction of turning of the propellers has any influence upon the maneuvering qualities of vessels having shafts well separated, propellers deeply immersed, and the action of one propeller uninterfered with by that of the other, the dead wood preventing this interference.

In torpedo boats and destroyers, however, this difference in turning properties may possibly exist. In such craft the shafts are close together; the tips of the blades when inboard are extremely close to each other; and the blades of the screws when upwards are so close to the surface of the water that they cause air to pass down to the screws, and thus produce an appreciable difference in the densities of the medium in which the blades work.

*Causes that will produce effect upon turning effort.*

The effects of the above on turning effort are explained as follows: (a) Distance apart of shafts: A vessel in turning, by using her screws alone, may be regarded as turning about some point in her keel or keel prolonged as a center, the turning arm being equal to the athwartship distance between the shafts at this point. The closer the shafts are together and the greater the length of the vessel—or in other words, the greater the ratio of length of vessel to turning arm—the greater will be the power

required for turning. This ratio for torpedo boats and destroyers varies from 19:1 to 54:1, while for gunboats it is about 11:1, for cruisers 20:1, and for battleships 11:1, assuming that the turning center is in the midship section.

(b) Proximity of screws with absence of dead wood: A propeller is most efficient when working ahead, as the driving surface is then more nearly a true helical surface. Where one screw is turning ahead and the other astern, and the screws are so close together that no dead wood intervenes to prevent one screw from influencing the action of the other, the propeller that is turning outboard throws a certain amount of water directly across the other inboard-turning screw. This action changes the direction and velocity of flow and decreases the density of the propeller race, and seriously affects the propulsive efficiency of the propeller thus interfered with.

(c) Screws close to surface: Where the propellers are so close to the surface of the water as to break the surface and draw down air to the screws, the difference in densities of the medium in which the upper and lower blades work caused by this suction of air, will have its minimum effect when the outboard turning screw is driving ahead, and its maximum effect when the inboard turning screw is moving ahead.

*Continental navies find in-turning and out-turning screws equally efficient for maneuvering purposes.*

It is a matter of special significance that no complaint comes from either Germany or France in regard to the poor maneuvering qualities of their battleships. All the German vessels that have passed through the Kiel canal seem to possess exceptional maneuvering qualities, whether they have in-turning or out-turning screws.

A careful study of the French technical papers will also show that the Admiralty officials are quite well satisfied with the maneuvering qualities of their large battleships. Both the twin and triple-screw ships of that nation have some of each class fitted with in-turning and out-turning screws, and thus that naval power is best fitted to form a definite conclusion on the question, since comparative data can be secured.

Careful inquiry has also been made of the maneuvering qualities of the latest triple-screw Russian battleships that have been commissioned, and there seems to be no evidence that difficulty is experienced by Russian naval officers in maneuvering their largest vessels.

*Superior maneuvering quality of triple-screw installations.*

It should likewise be noted that the majority of the battleships of Germany and France, as well as some of Russia, have of late been fitted with triple screws. If maneuvering quality is of primary importance, then I have no hesitation in stating that we should look into the direction of such a distribution of motive power, rather than depending upon out-turning installation of propellers for this tactical superiority. This contention is sustained by the declaration of German naval experts, who have officially stated that the tactical advantages have been the impelling reasons which have influenced the German Admiralty in demanding that all the battleships of the home squadron be fitted with a triple-screw installation.

*Military reasons demand that definite information be secured upon this subject.*

The most cogent reasons upon the part of the designers in providing for an in-turning system of screws has been to secure efficiency and endurance in the engine room, for it is certain that breakdowns and accidents will be of more frequent occurrence if engineering reasons are to be needlessly sacrificed in the arrangement of the screws. It is as easy for the designer to provide for an out-turning installation as for an in-turning design, but the engineer has a right to demand that if a change is to be made, it should only be done after comparative experiment has been made, particularly as such experimentation would not involve an expensive outlay. It is certain that the future commanding officers of the Navy have the greatest interest in maintaining the in-turning installation, and that the ship which can be maneuvered most readily will be the one where it will be possible to answer bell signals most promptly, by the fewest possible number of men.

*Data, and not dogmas, will alone solve the problem.*

During the past ten years the Bureau has provided for as many installations of out-turning screws as in-turning screws, and it has only reverted of late years to the in-turning system because increased engineering efficiency has been secured thereby. It does not oppose a change, but it insists that the decision should rest upon the result of careful experiment, and not upon generalization that will not stand the test of experience or investigation.

Is it not possible that the difficulty experienced in maneuvering with inboard-working screws has been due to the fact that there has been a failure to recognize the fact that one must unlearn, if not partly forget, the method practiced when operating with the out-turning system?

GEORGE W. MELVILLE,
*Rear Admiral, Engineer-in-Chief, U. S. N.*

# THE NAVAL BOILER QUESTION IN FRANCE.

## RELATIVE MERITS OF LARGE AND SMALL-SIZE TUBES FOR BOILERS OF CRUISERS AND BATTLESHIPS.

During the past ten years there has been waged beneath the protective decks of the warships of all navies a spirited battle of the boilers. As naval efficiency is involved in the outcome of the result, the contest has caused engineering experts to give special study to the problem of finding for their respective navies an approved type of water-tube boiler that would be light in weight, economical in space as well as in coal consumption, capable of severe forcing, and possessing an endurance surpassing that of the Scotch design.

In all navies there have been installed in warships, for experimental and other purposes, water-tube boilers that not only gave trouble shortly after the time they were put to use, but which have been proved to be absolutely unsuitable for the severe and unusual conditions to which warship boilers must be occasionally subjected. And thus the question of the water-tube boiler in every naval service is one that is far from being satisfactory to engineering experts. There can be no return to the Scotch boiler, and therefore naval experts must strive to improve the water-tube design rather than attempt to dispense with such type.

From time to time of late the statement is made that the modern water-tube boiler is as heavy as the Scotch design. The weakness of this statement rests in the fact that water-tube boilers carrying 240 pounds pressure are compared with cylindrical boilers carrying 160 pounds. Thoughtful engineers are, however, asking the question "Why use 240 pounds steam pressure? Is not 200 pounds a sufficiently high limit?" It is certain that if the same pressures were carried in the Scotch type that are carried in cylindrical types, the shells would have to be made so thick, and the plates would be so severely strained in flanging and working, that constant trouble would be experi-

enced with the cylindrical design. The rapidity of getting up steam in the water-tube boilers, and the ability of replacing them without disturbing the protective deck, constitutes a military advantage that will make it impossible to return to the Scotch design. By a process of elimination, approved types of water-tube boilers are now being selected, which will undoubtedly possess the essential requisites demanded for naval purposes.

As England has the largest navy, and did much pioneer work in the boiler line for others, her story of surprise and disappointment was the first to be heard. About four years ago her naval administrators awoke to the fact that this battle of the boilers promised to impair her naval prestige, if not her maritime strength. As a result of this apprehension, a Boiler Commission was appointed, and the several *ad-interim* reports submitted by this Commission have attracted so much attention and caused so much study to be given to the question that many of her naval experts now believe that the boiler problem has become the naval problem of the hour.

Events have occurred of late that seem to foretell that it will not be long before we ourselves will have the problem to solve of what to do with some naval vessels installed with boilers that are possibly too tender for service needs.

In France, likewise, the boiler question has been the subject of special and studious consideration. The following circular letter, addressed to the Vice-Admirals, Commanders-in-Chief, the Marine Prefects and Directors of private shipbuilding establishments, clearly shows that the Admiralty officials fully realize that the question is one which vitally concerns the efficiency of the navy. The communication is an exceedingly important one, and it will cause increased attention to be given to the question of finding one or several types of boiler suitable for various naval purposes.

As the boiler problem will be specially considered from several standpoints in this year's volume of the JOURNAL, the communication of the French Minister of Marine should form an important part of the projected symposium upon the question.

While publishing in its entirety this communication of M.

Camille Pelletan, attention is called to the fact that the Minister of Marine of France has been misinformed as regards the statement that no small tubes have been used in the boilers of the American warships of large size. Two of our battleships have been fitted with small curved-tube boilers of the semi-vertical, submerged-tube type. As both of these ships will be in commission within a year, the Navy Department will secure some very positive information as to whether or not such ships can be run for protracted periods without the boilers becoming impaired, or decreasing in efficiency.

The contract requirements of all our battleships also specify that a full-power trial of four hours' duration shall be conducted, and that the air pressure carried shall not exceed one inch. The speed demanded by contract requirements is so high that forced draft must be used on all boilers during that trial. While the specifications do not permit over an inch of water pressure to be carried in the fire rooms of very large ships, it is exceedingly doubtful if it would be ever possible for any contractor to secure a greater pressure, even though he was permitted to do so. With the closed-fire room system, there must of necessity be so many air leaks, especially through the bunkers, and in the boiler fronts and casings, that it would be practically impossible to secure higher pressure in all the fire rooms at the same time. This certainly applies to warships of over 6,000 tons displacement. Space has never yet been alloted for the installation of blowers of sufficient size to secure more than one inch of air pressure in all the fire rooms of a battleship or armored cruiser, and thus our boilers on official speed trials, with one inch air pressure, are practically subjected to the severest conditions possible. If, however, only a portion of the boilers are used and all the blowers kept in operation, a greater pressure than one inch can undoubtedly be secured in one or a number of the fire rooms.

It can also be expected that every navy will demand that the approved type of boiler for future use shall in an emergency be capable under forced-draft conditions of burning, for at least six continuous hours, more than 30.9 pounds of coal per hour per square foot of grate.—[The EDITOR.]

## OFFICIAL ORDER OF THE FRENCH MINISTER OF MARINE.

PARIS, *February 12, 1903.*

The following order, relating to the selection of boilers for large warships and to the trials to which they should be subjected, is herewith brought to the attention of the Board of Admiralty.

The choice of the best type of boiler suitable for war vessels has occupied the attention of all naval powers for years. The demands for an ever-increasing speed has made this question not one alone of safety and economy, but, more important still, one of preponderating military importance. I find, however, that there exist in France at this date differences of opinion and of practice upon questions which appear to have been finally settled in other countries.

For a long time, small-tube boilers have, for good reasons, been considered a necessity for torpedo craft. By means of such installations the speeds hitherto attained have been realized on very small displacements. As in many branches of industry France has had the honor of having taken the initiative, it has been so as regards small-size tubes for boilers of certain classes of vessels. The temptation to extend the advantage derived from the installation of boilers of the small-tube type by introducing them into ships of great displacement, is readily understood. But there is an apprehension upon the part of a number of competent judges that their introduction into some of our recently-constructed cruisers has hardly been justified by the results secured. The fact that there is apprehension on this subject is incontrovertible.

The small-tube boilers have two drawbacks, other things being the same. Their grate surface is so limited that in order to obtain results comparable with boilers of large tubes strong forced draft is necessary. This entails extra and severe work on the fire-room complement. Those firing the small-tube type of boiler are thus obliged to handle in the same time and within the same space double the weight of combustible ordinarily consumed with steam generators fitted with larger tubes. Hence there also arises a very rapid clogging of grate bars, due to the accumulation of ashes and clinkers, thus entailing additional labor upon an

already overworked force. The result of such firing must be accompanied by a corresponding loss in efficiency.

The gravity of these defects is not realized to its full extent when the small-size tubes are installed in boats that are designed to make comparatively short runs, and that are not expected to operate far from their base. In view of the exceptional speed desired of torpedo boats and destroyers, boats in which the installation of small tubes is effected, the loss in efficiency must receive but comparatively little consideration, particularly as speed is not only the chief end of the design, but is the principal safeguard of this type of craft. It ought to be practicable, however, to improve these exceptional adverse conditions as regards the coal consumption in torpedo boats by carefully selecting a specially-prepared fuel. The rapid clogging of the grate and the low efficiency of the boilers of torpedo boats might thus be guarded against.

The case is far different when we regard ships destined to make long voyages with such fuel as may be obtained at the several coaling ports that are visited by our ships of war. It should be borne in mind that the small tubes are more exposed than the large ones to deteriorating agencies; that it is almost impossible to inspect them, and that the difficulty of finding leaky tubes makes such design of boiler difficult to repair.

On official trials, when the boilers are new, where the coal is picked, where the trial is of short duration, and a special crew of experts is secured, this class of boiler shows quite satisfactory results. But as soon as the small-tube boilers are used under conditions approximating those of actual cruising service, the delusion that they are suited for vessels of large tonnage vanishes. The coal expenditure then increases fifty per cent. above that used on trial. The steaming radius of action of the ship correspondingly shrinks.

Since the naval complement in the fire room is always much smaller than that detailed for the trial trip, it becomes difficult, not to say impossible, to obtain the same degree of forcing of the boilers, and thus secure the horsepower desired. When this type of boiler is subjected to extended service the heating surface be-

comes less efficient, and many of the advantages which are found under trial-trip conditions disappear.

Such appears to have been the concensus of opinion of other naval powers. Not one amongst the most powerful maritime nations has been tempted to follow our example. Neither England, the United States, Russia nor Italy places small-tube boilers on their ships, except upon craft similar in tonnage to our torpedo boats. If Germany has employed them in her ironclads, she has done so in conjunction with a type of boiler most widely divergent in design, viz: the cylindrical boiler of the merchant marine. Where this combination of cylindrical and water-tube boilers has been installed, it is designed that the cylindrical type shall be used for ordinary cruising, while the water-tube steam generators are held in reserve, to be used only when the maximum speed is desired.

Even this highly ingenious combination of widely divergent types of boiler does not appear to have been as successful as was anticipated. It is true that in some other countries, notably Holland, Sweden and Norway, small-tube boilers have been installed on ships of considerable size, but never on vessels exceeding a displacement of 5,000 to 6,000 tons.

We are, then, absolutely the only one Power which has attempted to drive ships from 8,000 to 12,000 tons displacement with boilers of this description. It is not because boilers of the small-tube type are not well known and advertised abroad. The manufacturers of small-tube boilers have never succeeded in getting them adopted for ships of great displacement. It is particularly interesting to read that the English Admiralty, long interested in the importance of the question of the choice of boilers, has constituted a commission of experts to report on the value and the proper use of the boilers of all types. This Boiler Commission, after study of all phases of the controversy, has made a preliminary report, wherein it is recommended that small-tube boilers should not be used on warships larger than cruisers of the third class. With us a different course has been pursued, even in the face of the adverse report and protest of the "Council des Travaux."

The hope was indulged in that our action would be one of progress, and would place us in the lead of other nations. This hope has been frustrated. The disparity between results obtained on trial and those secured in actual service have in too many cases justified the apprehension that exists. I have taken special care to consult with representatives of the corps best qualified to give advice upon the question—the corps that is charged with the operation of the boilers. As these officers are in continual contact with such boilers, they have excellent opportunity to note their good qualities and their faults. The opinion of the committee of our engineers conforms with the views of engineers in foreign navies, namely: that small-tube boilers should not be used on ships of great displacement.

In consequence of the consultation referred to, I have decided to install on our new armored cruisers only boilers of the types recommended to me as suitable by the Committee of Naval Engineers. The third recommendation of this committee has appeared to me no less important and worthy of adoption. Upon this suggestion are based the instructions relating to the boiler trials of ships of our Navy.

In the first place it is proposed to establish for the trials of our ships moderate rates of combustion, somewhat similar to those which can be demanded and expected under normal cruising conditions; that is to say, a combustion of from 100 to 110 kilograms per square meter of grate surface (about 22.54 pounds per square foot). It is manifestly a species of self-deceit to base the engine power on a performance with forced draft. Such condition is only obtainable with extraordinary exertion on the part of the personnel, with machinery new or recently overhauled and for a period extending over but a short space of time. It is also well known that the boiler efficiency decreases as the rate of combustion increases.

The system to be adopted, therefore, involves economy in fuel, so that either the radius of action for the same coal supply will be extended or a saving of weight will be realized with the radius of action remaining the same.

Is it, then, the intention to do away with forced draft entirely?

Not at all. Instead of considering forced-draft conditions as the normal ones, it is proposed to regard forced draft as a reserve power which may be invoked in time of need. It is necessary in effect always to consider that part of the boilers may not be in condition for use, either because they are in need of cleaning or have suffered injury in battle or met with accident.

In a case where the expected work of a ship had been calculated only upon forced-draft conditions any injury to the boilers would seriously interfere with the results anticipated. According to the plan which I have adopted, the power desired could still be developed with only three-quarters of the boilers subjected to high forced draft. This would necessitate, however, a coal consumption of 150 kilograms per meter of grate surface (30.74 pounds per square foot). Such test will in future constitute the condition for the second trial to which the boilers of our ships will be subjected.

The duration of these two trials should also be increased. The natural-draft trials have been for some years rather too short in duration in our Navy, and were still further shortened after the introduction of small-tube boilers. The length of a trial should be such as to furnish an indication of what the tested boilers would do under conditions approximating those of actual cruising, and should not be adjusted to suit the frailties of the particular boiler experimented upon.

Large vessels designed for continuous cruising must have a trial exceeding three or four hours' duration if the adequacy of the boiler is to be demonstrated. Under normal conditions of coal consumption a duration from eight to twelve hours should be fixed for the test. A trial of the duration now demanded will suffice for the test when three-quarters of the boiler power is under forced draft.

In this matter of the duration of trials, I am only extending to France methods of practice recognized as necessary and reasonable elsewhere. All naval powers of the world conduct natural-draft trials of their ships, and the length of such trials is from eight to twenty-four hours. They all agree in making their

forced-draft trials of shorter duration than ours, using only a part of the boilers during such test.

There exists, therefore, solid reasons for the belief that the foregoing regulations are founded on a just regard for the needs of a war fleet. We do not build costly war vessels to obtain trial results more or less brilliant. It is our purpose to create ships which in service and in time of battle will realize their country's hopes and expectations. In order to obtain such a result we should as early as possible make the trial conditions approximate to those which the ship is destined to meet in fulfilling its high mission of constituting its country's defense.

I have decided in consequence that in future the full-power trials of ships of great tonnage will embrace:

1. A trial extending over ten hours with all boilers in operation.

2. A trial, extending over three hours with but three-quarters of the boilers in operation under forced draft conditions.

M. CAMILLE PELLETAN.

# THE PROBLEM OF BUILDING WARSHIPS ON THE GREAT LAKES.

By H. C. Sadler, Associate.

Professor of Naval Architecture and Marine Engineering, University of Michigan.

---

With the conditions of armed peace which obtain at the present day throughout the world, it is necessary that every first-class power should possess a navy. In the case of nations whose commercial interests are widely distributed, the possession of a strong naval force, capable of doing distant work, has in many cases proved more than a powerful moral factor in connection with international disputes. It is not intended in the present article to discuss naval policy, but it may be taken for granted that, under existing international affairs, the United States must continue to keep her place amongst the maritime nations of the world.

The building of a navy, however, involves many considerations. Provided that the country is capable of producing the raw and manufactured articles required in the construction of a war vessel there are two methods by means of which a navy may be built up. First, the government may establish dock yards and engineering works suitable for the building of vessels of the required number and size, and secondly, the contract for the construction may be let to private individuals or firms and carried out under the supervision of the government representatives. A third possible method is to have the vessels built in some other country. Such a policy is undesirable, except in special cases for many reasons, and need not here be discussed.

The policy of a nation building its own warships has perhaps reached its highest state of development in Great Britain and France, where it is possible, by reason of the proximity of the

Copyright, 1900, by Detroit Photographic Co.

LAUNCH OF THE STEAMER "HARVARD."

dock yards to maritime and manufacturing centers, to do the work comparatively reasonably and rapidly as compared with private firms. But even in these countries, since the adoption of implied or defined naval policies, and owing to the demand for speedy delivery of vessels, it has been found impossible to construct more than fifty per cent. of the battleships and cruisers in the government establishments. The small vessels, such as torpedo boats and destroyers, are built almost exclusively in private yards. In fact, if Great Britain and France had relied solely upon the admiralty dock yards to carry out their latest programmes, there would have been such delay in building the vessels that some of the first vessels to be constructed would have become somewhat obsolete before the last were finished. The same is true in other countries, the government dock yards being a necessity for repair and commission purposes, but performing a small part in the actual building of the Navy.

In the United States this question has been carefully considered, and the comparative ability of the navy yards to build as cheaply, efficiently and rapidly as the private concerns is now being tested. When it was decided, some seventeen years ago, to rehabilitate the Navy, one of the first problems with which the government was confronted was the ability to construct the required ships with the resources and facilities in existence. Few, if any, of the government dock yards were properly equipped to undertake the construction of modern vessels, especially in any numbers, and the authorities were therefore compelled to turn to the private builders for help in carrying out the required work.

At that time, owing to the moderate naval programmes projected, the resources and equipment of a few firms which were capable of constructing the necessary ships proved ample for the needs of the Government. But the day of small vessels and moderate programmes has passed, and, owing to the events that have occurred during the past few years, the United States must of necessity increase her Navy. The continual increase in size of warships that is taking place has narrowed the field of contractors capable of building such large vessels to small limits, until today there

are less than a dozen shipyards to which such work can be entrusted. As the Government has always had difficulty in retaining the services of skilled men at navy yards, and as the purchase of Government material cannot be expedited as in the case of private firms, the Navy Department would seem to be at a disadvantage in undertaking such work. The private shipbuilders have, therefore, played the most prominent part in the construction of the present Navy, although in many instances they have probably been enabled to arrive at their present state of experience and prosperity by the helping hand which the Government held out to them in the early days.

The time required to build a modern war vessel has an important bearing upon the fulfillment of a naval programme. Especially is this the case where the shipyards that are capable of building war vessels are limited in number. From the point of view of dispatch, as well as economy, the larger the number of private shipyards capable of doing this work the better for the nation. In times of stress the resources of the few experienced ones would be taxed to the utmost, while the inexperienced would be of small assistance in making good the deficiency. It is the old story of the man with the gun—he does not often want it, but when he does he not only wants it badly, but wants one that will work. The latest naval programme of Great Britain forms one of the most striking illustrations of the benefit accruing to a country by having a large number of shipyards capable of building war vessels. Here a case has arisen where the Government requires a large addition to its fleet in a comparatively short time, and is only able to carry the purpose into effect by the aid of private shipyards.

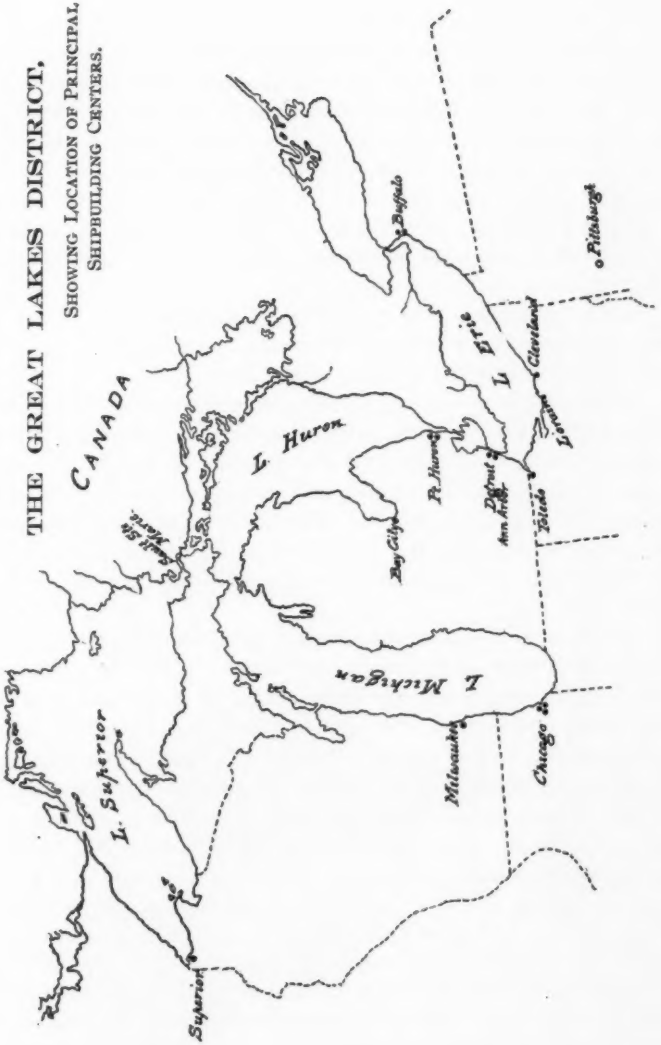
In the United States at the present day there are some ten shipyards which undertake the larger Government contracts. Most of these are situated on the coast, but there is still a large region where the shipbuilding industry has been flourishing for a number of years, and which, up to the present, has not been used to assist the Government in building up the Navy, viz: the Great Lakes. In this district there are some fourteen shipyards and engine shops, well equipped with modern machinery and

Copyright, 1900, by Detroit Photographic Co.

STEAMER "MARIE."

THE GREAT LAKES DISTRICT,

SHOWING LOCATION OF PRINCIPAL SHIPBUILDING CENTERS.



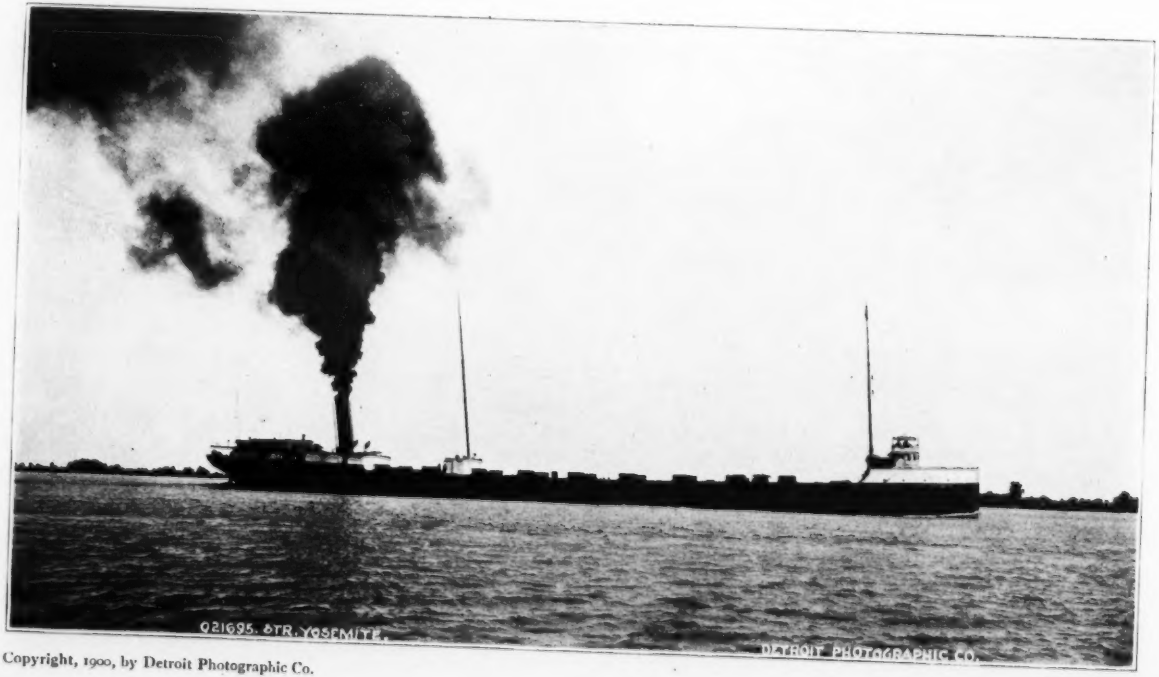
capable of building vessels up to five hundred feet in length, and some forty smaller yards.

With regard to drydocks and marine railways, there are thirty-nine, one over 600 feet, three over 500 feet, seven between 400 and 450 feet in length, with draughts on sills varying from 19 feet to 21½ feet, besides many smaller ones in the neighborhood of 300 feet in length. The navigation period varies, but on the average is open from the second week in April until the second week in December. During the last two years some forty steel vessels have been built on the lakes each year, and this does not include small craft, such as tugs, etc.

With such shipbuilding facilities at hand, it is the object of the present article to discuss the means by which these could be utilized to help in the building of the Navy.

The principal points that will be considered in connection with this subject are: (1) The present agreement with Canada and Great Britain with regard to the question of warships on the Great Lakes. (2) The means of getting vessels built on the Great Lakes to the coast. (3) The ability of the lake shipyards to construct war vessels. (4) Whether the cost of construction in this region will compare favorably with that of yards on the sea coast.

There is no formal treaty between the United States and Canada with regard to keeping armed vessels on the Great Lakes; the present *modus vivendi* dating from an agreement between these two countries of April 28, 1817, and comprising two letters between Mr. Bagot and Mr. Rush. According to these, each country agrees to confine itself to the following vessels: "On Lake Ontario to one vessel not exceeding 100 tons burthen and armed with one 18-pound cannon. On the upper lakes to two vessels not exceeding like burthen, each armed with like force; on the waters of Lake Champlain to one vessel not exceeding like burthen and armed with like force." It further states that, "all other armed vessels on these lakes shall be forthwith dismantled, and that no other vessels of war shall be there built or armed;" and that "if either party should hereafter be desirous of annulling this stipulation and should give notice to that effect to




Copyright, 1900, by Detroit Photographic Co.

the other party, it shall cease to be binding after the expiration of six months from the date of such notice."

Situated as the United States and Canada are in this region, it will be generally conceded that the above agreement, so far as *keeping* armed vessels on the lakes is concerned, is a wise one. The small vessels above mentioned simply fulfill a general police duty, and it would without doubt militate against the interests of both countries to keep these waters patrolled by regular fleets of war vessels. If this agreement should be discontinued, then each time one country commissioned a vessel the other would of necessity have to do likewise, and a state of affairs would eventually be produced similar to that which obtains in Europe at the present day.

The second part of the agreement, however, stipulates that "no vessels of war shall be there built or armed." When this agreement was made the Great Lakes were purely inland seas, and therefore ships built on their shores were destined to remain in these waters. It was impossible at that time for vessels of any size that could be built in these regions to be taken to the coast. Now, however, with the completion of the Welland Canal, vessels up to 260 feet in length are enabled to pass from the lakes to the sea. Since these waters are practically open to the sea, it seems reasonable that, provided each country would agree to let the first part of the present agreement stand, *i. e.*, not to *keep* war vessels on the lakes, there should be no objection to either country building war vessels there if, on completion or, if necessary, before the armament were put on board, these vessels were to be taken to the seaboard.

In fact, as the treaty now stands, if all of the converted yachts used in the late war with Spain had been built on the lakes (and some actually did come from these waters), no objections could have been raised as to their use as gunboats, provided that they were not armed before they left that region. Most war vessels in any case have to be taken to the navy yards to complete their outfit, so the question of arming these at the lake shipyard is not of very serious moment.

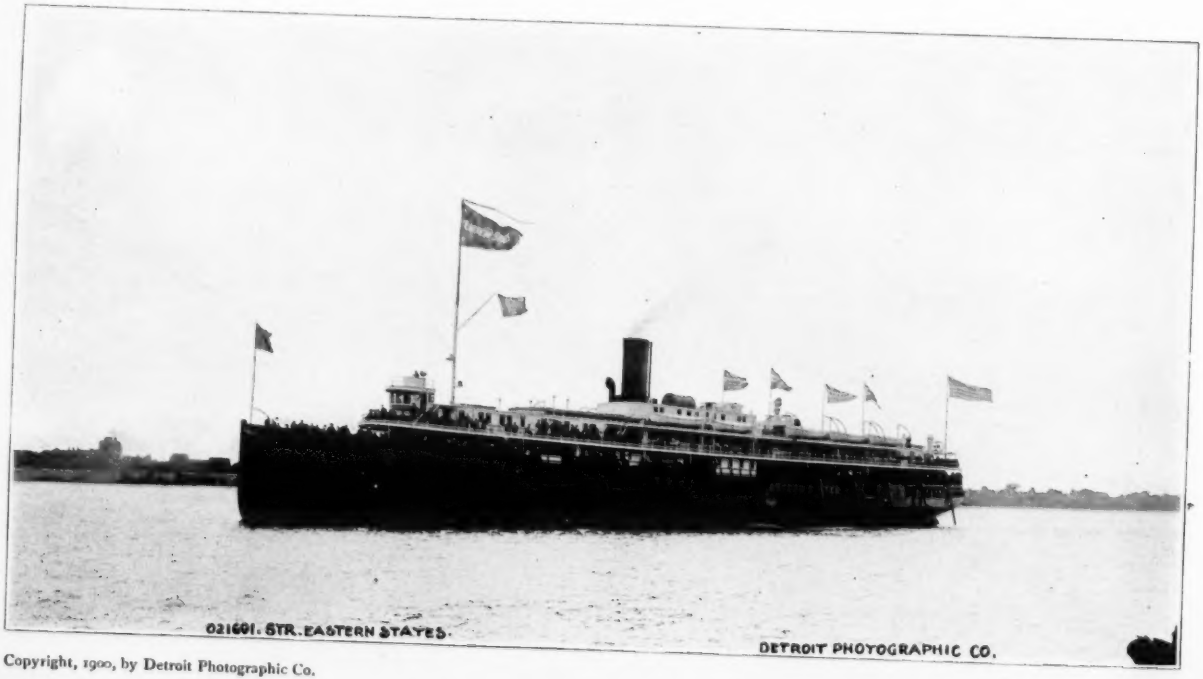
The spirit of the present treaty is that neither country should

keep a fleet of war vessels on the Great Lakes, and this principle, as mentioned above, should be observed by both nations; but with the waters of the Great Lakes now open to the sea, and with the possibilities of more outlets in the near future, the clause as to building war vessels does not have the same weight today as as it did when the agreement was first signed. Speaking without the weight of authority, it is nevertheless the writer's opinion that neither Canada nor Great Britain would raise objections to the reconsideration of this matter, as it is one that would affect both countries in the same manner.

In the event of such an agreement as above outlined, the question which would confront this country would be a proper outlet to the sea. At present the only way for vessels of any size is by means of the Welland Canal and St. Lawrence River, practically in Canadian territory. The largest size of vessel that can be taken through this canal is one of approximately 260 feet long by 40 feet broad and drawing about 14 feet of water. All vessels, therefore, of the small cruiser or gunboat type could readily be taken to the coast by this route. The United States does not at present possess any outlet approaching this size, and although a discussion as to the advisability of this Government providing a ship canal to the coast is beyond the scope of the present paper, this question is one that cannot be too strongly urged by everyone who has the maritime interests of the country at heart.

The contemplated Erie Canal improvements, though necessary, do not attempt to give the outlet required, and this will be, as its name signifies, simply a "barge" canal. The report of the United States Deep Waterways Commission of 1896 discusses all the principal canal routes from the lakes to the sea, and amongst its conclusions it is stated that, in the opinion of the commissioners, a channel of not less than twenty-eight feet in depth should be constructed, and that this was a perfectly feasible project. Such a canal would fulfill all the requirements of a barge canal, and would at the same time give an outlet for larger vessels.

The argument that vessels suited for lake work are not suitable for seagoing purposes is generally true as regards the large freighters, but many of the smaller and coasting type could be




Copyright, 1900, by Detroit Photographic Co.

made suitable for both purposes. In any case, provided that canal charges were not excessive, a great saving would be effected if vessels could carry their cargoes directly to a seaport and there discharge into seagoing vessels. In the latter case the cargo is only handled twice, whereas with the present method it must be handled at least four times. It may not be generally known that a number of vessels ply on the Great Lakes in summer and engage in sea work during the winter months.

The opinion seems prevalent, especially amongst people on the coast, that the vessels plying on the Great Lakes are somewhat roughly built, and that work suitable for lake vessels would not pass muster on the coast for seagoing work. There is, no doubt, a certain amount of truth in the above, but the general statement requires considerable modification. In the first place, it should be clearly understood that as far as the typical lake freighter is concerned, these vessels are built solely for the purpose of carrying as much cargo as possible upon a limited draught.

In general arrangement they are designed to fulfill conditions which do not obtain on the coast; structurally they are arranged to suit these conditions, and they are, for the work they have to do, relatively as strong as the corresponding type of seagoing vessel. The question of appearance does not enter into the design, or, if it does at all, it is of comparatively small moment. Provided that the vessel is built of good material and all parts properly riveted, minor details, such as slight unfairness in the plate edges and the like, do not affect the structure from the point of view of its efficiency for the purpose for which it was designed.

In fact, on account of the service that these vessels have to perform it would be so much waste of energy and money to put on what may be called a high finish. The writer's observations go to show that these vessels compare very favorably with the similar type of vessel built for seagoing purposes in the home of the "tramp" shipbuilding industry viz, the northeast coast of England. It should be clearly understood that the lake freighter is not exactly "thrown together," but simply that a fine finish to the work is neither demanded nor exercised.

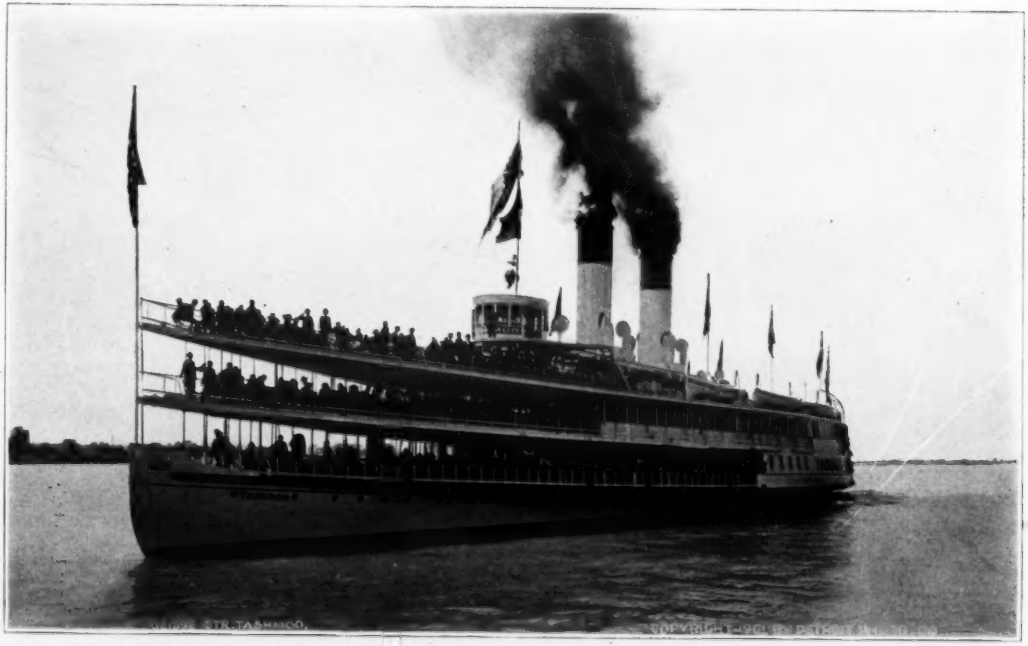
There is no occasion to apologize for the lake freighter; but, since this type of vessel is perhaps the most common on these waters, and one is apt to judge the abilities of lake shipbuilders from a few isolated cases, the above points have been mentioned to disabuse the minds of some who may have formed erroneous ideas as to these vessels. The freighter is not, however, the only type of vessel on the Great Lakes.

The combined cargo and passenger and the purely passenger and excursion types form object lessons to any one who doubts the ability of the shipbuilders in these parts to turn out first-class work, and such as will bear comparison with the best that can be produced in any of the coast yards. Here, when fine finish and neat work is required, these conditions are fulfilled, and, strange as it may seem, by the same workmen that build the freighters.

After all it is a question of the workman, and, seeing he is very the same man who is sometimes in one place and sometimes in another, there should be no reason why his work in one place should be inferior to that in another. Many illustrations could be given of vessels of this latter class; but a few, such as the *Northland* and *Northwest*, *Eastern* and *Western States*, *Manitou*, and the vessels of the Detroit and Cleveland, and Detroit and Buffalo lines, as well as such excursion vessels, as the *Tashmoo*, etc., may serve as showing that, when the occasion demands, the lake shipyards can turn out high-class work. The several half-tones show representative types of steamers plying on the Great Lakes.

Within the last few years a number of vessels have been built on the lakes for seagoing purposes, most of them under Lloyd's supervision, and any one who has had occasion to come in contact with this august body will realize the small chance that anything but first-class work has of passing its somewhat exacting requirements.

There can be no doubt, therefore, that on the score of workmanship demanded in war-vessel construction, the shipyards of the Great Lakes would have no difficulty in fulfilling all the requirements.



Copyright, 1900, by Detroit Photographic Co.

STEAMER "TASHMOO."

In the minds of some there still exists the idea that ships can only be built on or near the coast line of a country. Provided that there are adequate means of getting vessels to the sea, the actual point at which they may be built need not necessarily be determined by the fact that they must eventually operate in salt water. In fact, the nearer the manufacturing plant is to the plant producing materials required in its work, the cheaper in general will be the cost of the finished article. So in the case of a ship, it is cheaper to move it a given distance when finished than to pay the freight for the corresponding distance on all the raw materials used in its construction.

The cost of construction may be divided into two parts, viz: material and labor. The labor cost, for all practical purposes, may be taken as being approximately constant in similar yards with similar equipment. Where general shop arrangements are inferior the cost of labor will naturally be greater than where these are kept up to date. As far as the hull proper is concerned, the cost of material includes that of iron and steel, wood and outfit; and of these that of the iron and steel forms one of the principal items. This cost may be taken as meaning the cost of material delivered at the yard, and this depends upon the cost at the mills plus that due to transportation to the works. It is evident that the nearer the shipyard is to the production of iron and steel the cheaper will be the cost of this item. The actual proximity of the two, as above stated, does not, however, govern the situation entirely.

The cost of transportation by water is usually much less than by rail; and of two works so situated that one is enabled to get its material by water and another by rail, the former will in general pay less for transportation than the latter. This last remark has special bearing in connection with the shipyards situated on the Great Lakes. A casual glance at the map of the United States will show the immense tracts of country in direct connection with these waters. From the rich ore deposits of the Lake Superior region to the many manufacturing centers of Ohio, Pennsylvania and New York State is one continuous line of communica-

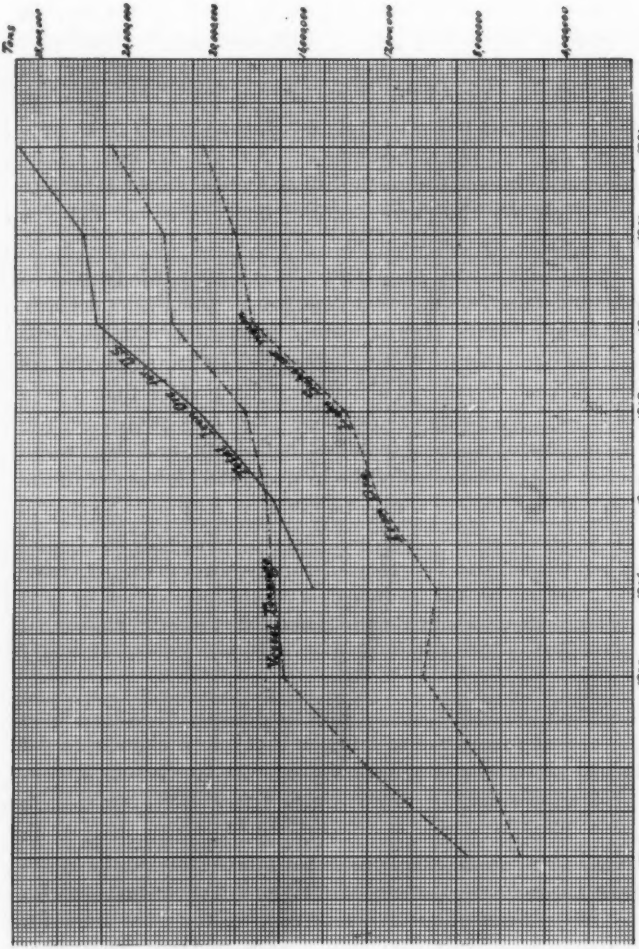
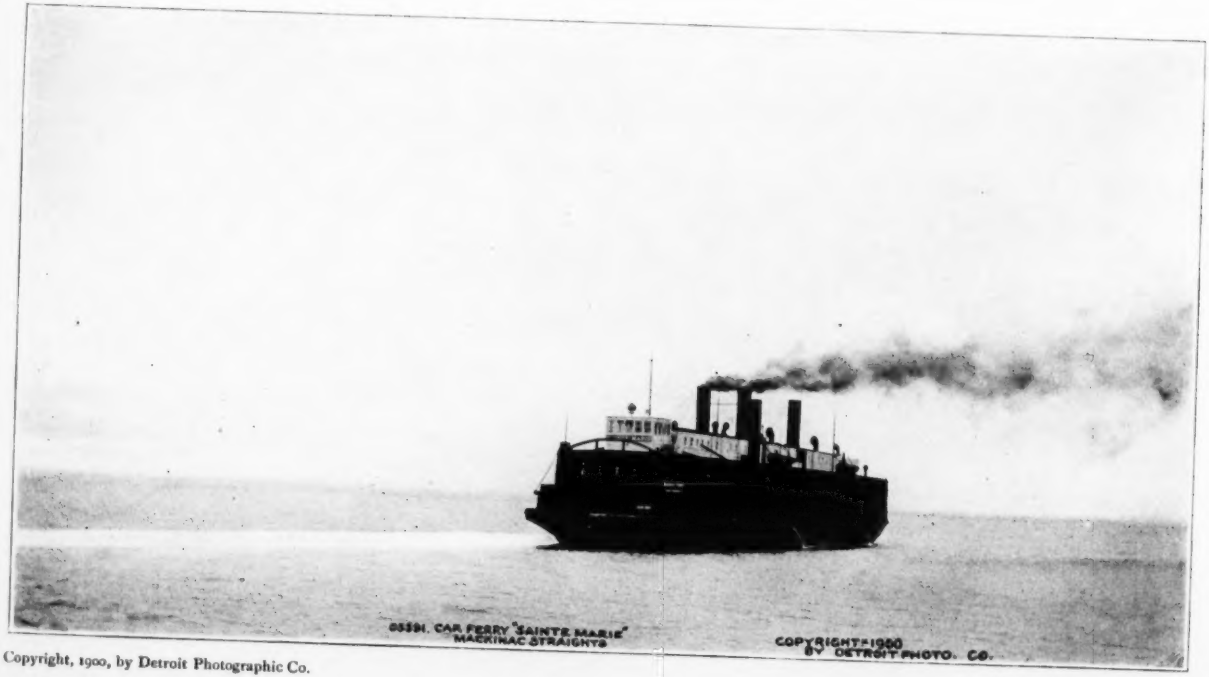


DIAGRAM SHOWING THE PRODUCTION OF IRON ORE FOR THE LAKE REGION AS COMPARED WITH THAT OF THE UNITED STATES.




Copyright, 1900, by Detroit Photographic Co.

tion, where the transportation charges are the cheapest in the world.

A comparison of these charges with those of the railroads may prove of interest. During the year 1901 the average rate per ton mile was .99 of a mill, or less than one-tenth of a cent, while on the railroads the best rate was 3.5 mills. The average of the figures for the past ten years is: for lake transportation, 1.04 mills, and for railroads, 3.75 mills.

The near future will doubtless see a great development of manufacturing industries of all kinds along the shores of the Great Lakes. Already there are a number of steel and iron works, such as those at Chicago, Detroit, Cleveland, Buffalo, Loraine and at other points with deep-water terminals. The proximity of the ore deposits to available sources of water power, such as that at the Sault Ste. Marie Falls, will tend, for reasons stated above, to bring steel and iron manufacturing industries to such points. Even the leading steel and iron center, Pittsburg, is nearer to many of the Lake Erie ports than to any of the principal coast cities. Within a radius of about two hundred miles from Pittsburg there is practically included all the lake cities between Buffalo and Detroit. The majority are well within this radius. The distance from Pittsburg to Philadelphia and New York is one hundred miles farther than to Lake Erie ports. So far, then, as the lake and Atlantic coast shipyards are concerned, as regards securing iron and steel used in the construction of both hull and machinery, the difference as to cost will be to the advantage of the lake establishments.

Actual comparative costs of vessels built on the Great Lakes and the seaboard are difficult to obtain, as the types are dissimilar. The conditions of trade, fresh water as against salt, method of construction, cause variation in design that tend to vitiate direct comparison. Judging from a few cases where comparison is possible, the cost of vessels built in these districts is slightly lower than that of similar vessels built on the coast. An objection may be raised to the last statement that in some cases of small government vessels upon which both coast and lake yards have been asked for bids, the former has obtained the

contract. The result has been disastrous to the bidder, and such cases simply show that occasionally methods of estimating costs are superior in the lake yards. The cost of a vessel is not necessarily its contract price, as many have found out to their sorrow. The difficulty sometimes lies in the fact that the plans and specifications for a vessel are not consistent with the amount of the appropriation. It is true that in general, government vessels are relatively more costly than merchant ships, due to a number of causes, some of which have received considerable discussion; but this is, or ought to be, a well-known fact, and should be allowed for in making up the contract price. In case of loss the fault lies largely with the bidder, and not altogether with the Government.

Another factor which enters into the cost of construction is the time required to build the vessel. A few examples of the time taken for various types of vessels built in the lake shipyards may be of interest in connection with this subject:

| Type. | Length. | Launched, days. | Delivered, days. | Weight of metal. |
|---|---|---|---|---|
| | *feet.* | | | *tons.* |
| Bulk freighter..... | 410 to 420 | 175 to 180 | 220 to 250 | 2,200 to 2,400 |
| Package freighter.... | 360 to 380 | 214 to 217 | 240 to 270 | 2,000 to 2,200 |
| Passenger steamers.. | 360 to 370 | 260 to 270 | 430 to 450 | 1,200 to 1,300 |
| River steamers..... | 270 to 300 | 330 to 340 | 450 | 400 to 450 |

The above table is made from vessels as actually built, no deduction being made for delays of any kind. The number of days to the time of launching and delivery are reckoned from the time of signing the contract, not from the first delivery of material. It will be noticed that the time for the river steamers, as given, is long, compared with the other types; but in this case the delay was due to failure to get material. With prompt delivery the figures would be reduced to about 200 and 250. The actual recorded time for one of the large type of freighters, from the laying of the keel to the launch, was ninety days. It also frequently happens that, owing to the state of navigation, a vessel is completed some time before actual delivery, so that the times, as given, do not represent the best that can be done. It was,

Copyright, 1900, by Detroit Photographic Co.

GREAT NORTHERN ELEVATOR AND SHIPPING, BUFFALO, N. Y.

however, thought preferable to give actual figures, including delays from all causes.

In this article an attempt has been made to bring out the possibilities of the lake shipyards and engine works with regard to government work; and it has been shown that so far as quality of workmanship, cost of production, and speed of building is concerned, there is nothing to hinder these yards from competing successfully with any in the country.

The two obstacles at present in the way are the standing agreement with Great Britain with regard to building war vessels on the Great Lakes, and the absence of adequate facilities on the United States side for getting vessels so built to the coast. Both of these, and especially the latter, should receive the immediate attention of the Government, as apart from the purposes here discussed, the commercial advantages that would accrue from opening up the great region of the West to the coast would, in time, tell upon the prosperity of the country.

The United States must, as years go by, increase her merchant marine, and everything that is possible should be done to foster shipping and shipbuilding. With an adequate outlet to the sea the shipyards of the Great Lakes would be immediately brought into play to help in building up this industry.

One other point which, although not immediately connected with the subject under discussion, yet has an important bearing, is what may be called the moral effect that the building of war vessels on the lakes would entail. To the vast inland population who are engaged mainly in farming and the allied industries, the necessity of a strong navy does not appear evident. They seldom, if ever, see a war vessel of any kind, and the building of such upon the Great Lakes would not only tend to create an interest in their construction and welfare, but would do more to arouse patriotic instincts than any number of speeches.

# THE CAVITE STEEL FLOATING DRYDOCK.

## ITS STRATEGIC VALUE IN DEFENDING THE PHILIPPINES.

By Civil Engineer A. C. Cunningham, U. S. Navy.

The Congress of the United States, in the act making provision for the support of the naval service, which was approved July 1, 1902, authorized the expenditure of $1,225,000 for a steel floating drydock for the Cavite Naval Station. The act provided that the material of the dock should be of American manufacture, and that it should be constructed under the direction of the Bureau of Yards and Docks, Navy Department.

### CONGRESSIONAL APPRECIATION.

Thoughtful consideration will show the wisdom of this action, and the quick appreciation of the military situation in the Philippines. A few months before the naval appropriation bill was enacted into law, the New Orleans floating drydock had been accepted, after it had demonstrated the capability of a well-constructed floating steel structure to dock safely a modern first-class battleship. The docking of the battleship *Illinois* in this structure had been accomplished under disadvantages and unusual conditions, and the test conclusively showed that such a design of dock possessed a distinct military value. The test also demonstrated that, owing to its properly limited elastic qualities, such a dock will carry a first-class battleship more easily and uniformly than the land or graving structure.

The behavior of and conditions surrounding the New Orleans floating structure in docking the *Illinois* had been particularly inquired into by the House Naval Committee, in connection with the question of the establishment of a graving dock for an extensive naval station in the Philippines.

The Spanish authorities had left unsolved the problem of selecting a suitable site for a permanent naval station. The Con-

gress was somewhat reluctant to authorize heavy expenditures for a naval establishment that would ultimately have to be defended by extensive land fortifications, and it was therefore believed that the nation's interest would best be secured by the construction of a floating steel structure which could be first used at Cavite, and then transferred to another point if necessary.

The problem of selecting a site for the most important naval station in the far east was regarded by the Congress as a very serious one. It was believed that reasons of national policy demanded that the question be postponed for a few years. The problem actually involved topographical, industrial, strategical and political considerations which were not easily reconciled. It was, therefore, undoubtedly a wise policy which prompted Congress to authorize the building of a floating dock at Cavite for temporary, if not for permanent, purposes.

### OUR PAST EXPERIENCE WITH GRAVING DOCKS.

While the question of authorizing the building of an extensive naval station in the Philippines was under consideration the Navy Department was experiencing considerable trouble in regard to the graving docks that had been in course of construction at several naval stations on the Atlantic coast. Not only were some of the contractors backward in the work, but it seemed essential at certain stations to cancel existing contracts. In the building of these structures some of the contractors had apparently forgotten to take into consideration the character of the soil in which the docks were to be built, the facilities for securing supplies and labor, the nature of the prevailing tides, winds and currents, and the danger from flooding. While the Department had taken special means to inform the several bidders as to the necessity of taking into consideration each and all of these factors, some of the successful bidders apparently had failed to consider all of the important features.

The delay in building the graving docks at the several navy yards, contrasted with the rapid delivery of the New Orleans steel floating dock, was undoubtedly an important consideration in securing the authorization for the Cavite structure. Our ex-

perience in building cement docks had conclusively shown that such structures could not be built in less than six years, while the floating dock could be constructed in just half that time. In the case of the cement or stone docks the cost in every case will practically exceed the estimates to a considerable amount, not taking into consideration the loss from delay. The floating structures were built at contract price. The New Orleans dock had also shown that the structure itself might contain repair facilities of considerable extent.

The floating dock also commended itself to the consideration of many members of the House Naval Committee by reason of the fact that the element of time in construction was in favor of the floating structure. Then, again, the dock could be towed to the shops, and in the case of the Philippines the shops might be a fleet of warships, while in the case of the graving dock a series of shops would have to be built. When a ship can be taken from the water it is a very unusual casualty which her own crew and equipment cannot at least make temporarily good, providing labor and material can be brought to the vessel in the dock. In the Philippines we have all manner of auxiliaries to the fighting ship, and if one of the battleships should reach the floating dock the auxiliary vessels could render much service, in bringing, where necessary, men and material from China and Japan.

The problem of commencing the building of a great naval station in the Philippines was therefore happily solved by authorizing the construction of a floating dock. This action will give the commander-in-chief of the Asiatic Station a dock that will safely carry any battleship under his command. The dock will also be available for use at least two years sooner than any stone or cement dock could be built. It will not only be serviceable for use at Cavite, but for any point in the Philippines which may be ultimately selected as the site for the naval station. The Navy Department will thus have more time to investigate the possibilities of other points than those already surveyed as a proper site for our central naval station. Altogether, a wise decision was reached when the construction of the floating dock for Cavite was authorized.

PRELIMINARY CONDITIONS.

The appropriation having been made, it lay with the Bureau of Yards and Docks to execute the project. That Bureau had just completed the best floating drydock in existence, and a less progressive naval establishment would have been satisfied to duplicate this dock. The Bureau, however, had given continuous study to the floating-dock problem during the construction of the New Orleans dock, and had taken careful note of all developments and happenings in this line.

It was found that although much more had been secured in this dock than had heretofore satisfied most nations, there were still many features desirable in the matter of strength, convenience and equipment in a floating-dock structure fully to meet the needs of an exacting and progressive naval service.

It was therefore determined to make a general specification covering all the desirable conditions, and to allow the competition of the world's experts in producing a design which should most fully meet the needs of the naval service.

THE SPECIFICATION.

The leading requirements of the specification are here given.

Paragraph 1. *Intention.*—"It is the declared and acknowledged intention and meaning to provide and secure a complete and substantial self-docking floating steel drydock of American manufacture, suitable for docking all the present and projected ships of the United States Navy, for which appropriations have been made, located and installed in perfect working order, together with all moorings, wharves, approaches, accessories and appurtenances necessary for the perfect, complete and convenient operation and maintenance, to the entire satisfaction of the Chief of the Bureau of Yards and Docks."

Paragraph 9. *Time of completion.*—"The dock proper shall be entirely completed and ready for test in every respect and particular within twenty-seven calendar months from the date of the contract."

Paragraph 23. *Plans and specification.*—"General Plans in sufficient detail to give the Bureau a perfect understanding of

the design of the dock, its method of operation, manipulation and construction, and of the character and distribution of all material, machinery and appliances shall be furnished by bidders. The general plans shall be accompanied by a specification, stress diagrams and calculations in further amplification of the design and its capabilities, with full explanations of all operations and manipulations. The character and make of all machinery and appliances shall be described in the specification, and all other details necessary to enable the Bureau to arrive at a correct and perfect understanding of what is proposed. The contractor shall furnish the Bureau with tracings of all general plans."

Paragraph 24. *Detail plans.*—"The contractor shall prepare detail plans in amplification of general plans showing all parts of the dock and its appliances. Triplicate blue prints of these plans shall be submitted to the officer in charge for examination and approval before any work is performed. Tracings of approved plans shall be furnished to the Bureau. Approval of detail plans shall be of a general nature, and shall not relieve the contractor from errors, discrepancies or omissions that may occur therein, which shall be remedied or supplied whenever discovered or required."

Paragraph 30. *Work to be done by the Government.*—"The Government will do all the necessary dredging at the final location of the dock."

Paragraph 31. *Location.*—"The location of the dock is at the Naval Station, Cavite, P. I., at a site to be selected, but the Government reserves the right reasonably to vary the location, as may be to its best interests, before the final acceptance of the dock. The contractor shall provide moorings, approaches and other necessary accessories and appurtenances suitable for the location finally selected by the Government."

Paragraph 32. *General description.*—"The dock in general shall be an open-hearth steel structure, so designed and arranged as to be readily self-docking without the aid of divers or auxiliary constructions. It shall be self-contained as to the operating machinery, and capable of being towed from place to place safely without auxiliary bracing. It shall be of the general type, com-

posed of watertight side walls and body or pontoons, with a general ⌊‾⌋ shaped cross section, and divided into sufficient watertight compartments to give great stability, there being not less than six transversely. Simplicity and certainty of operation and freedom from possible disablement in all operations shall be given careful consideration by designers."

Paragraph 33. *Length.*—"The dock shall not be less than 500 feet long over all, none of which length shall consist of bracketed platforms without lifting power."

Paragraph 34. *Width.*—"The dock shall have a clear width between fenders of not less than 100 feet."

Paragraph 35. *Height and draught.*—"The decks of side walls shall have not less than eight feet of clear height above the water, with 30 feet draught over 4-foot keel blocks."

Paragraph 36. *Lifting capacity.*—"The dock shall have a lifting capacity of not less than 16,000 gross tons, uniformly distributed over the entire length, with the main deck not less than two feet above the water, and with not less than one foot of water in the compartments."

Paragraph 37. *Unit stress.*—"No portion of the dock, or its connections, shall have a stress of more than 10,000 pounds per square inch under the specified loads, or 15,000 pounds per square inch in self-docking, with a wind pressure of thirty pounds per square foot of exposed surface."

Paragraph 38. *Shiploads.*—"The dock shall be designed to dock all classes of vessels of the United States Navy, either centrally or with the center line of the keel 1 foot off the center line of the dock, with a freeboard of 2 feet, and shall provide for bearing over the full length of the dock. Diagrams of weights, as far as available, will be furnished on application."

Paragraph 39. *Distribution of load.*—"The dock shall be so designed that the entire weight of a battleship may be safely carried by the main keel blocks, or one-half the weight on each line of docking keel blocks in whichever position the ship may be docked. The side walls shall be designed to take shoring at any point that may be necessary."

Paragraph 40. *Working deck.*—"The working deck of the dock

shall be flush plated and so strengthened that docking keel blocks may be placed in any position."

Paragraph 41. *Uniform pumping.*—" The dock shall be so designed that the specified unit stress shall not be exceeded when the dock is pumped uniformly from all compartments to a freeboard of 2 feet with any specified ship load docked centrally."

Paragraph 42. *Allowable deflection.*—" With any specified ship load docked centrally and all compartments pumped uniformly until the dock has a freeboard of 2 feet, the longitudinal and lateral deflection over the entire working deck of the dock shall not exceed 1 in 2,000. Within the limits of allowed deflection the ship load shall be assumed to be perfectly flexible."

Paragraph 43. *Keel blocks.*—" All keel blocks shall be of clear heart oak, of a uniform length of 5 feet, a width of 16 inches and planed to a uniform thickness of 12 inches so as to be interchangeable."

Paragraph 44. *Spacing of blocks.*—" Main keel blocks shall be spaced 2 feet on centers, and docking keel blocks 4 feet on centers.

Paragraph 45. *Block-sills.*—" Docking keel blocks shall rest on sills of clear, heart, long-leaf yellow pine, 16 inches wide and planed to a uniform thickness of 12 inches, so as to be interchangeable. The sills shall be of sufficient length to accommodate all the docking keels in the Navy."

Paragraph 46. *Sliding blocks.*—" Every third sill shall be fitted with a sliding block, and shall extend to within 2 feet of the main blocking and sufficiently outboard so that the blocks cannot be hauled off the sills."

Paragraph 47. *Drainage.*—"Athwartship and fore-and-aft drainage shall be provided on the working deck of the dock."

Paragraph 48. *Side wall decks.*—" The decks of side walls shall have a clear passage fore and aft of not less than 5 feet in width. They shall have a hand-rail on the outboard side and a 12 by 16-inch clear, heart, yellow-pine timber on the inside, fitted with fair leads and cleats."

Paragraph 49. *Passage.*—" Passage from one side wall to the other shall be provided."

Paragraph 50. *Communication.*—"Telephone or speaking-tube communication shall be provided from one side wall of the dock to the other, along the side walls, and to the engine rooms."

Paragraph 51. *Headline.*—"Provision shall be made for a central headline and for hauling the same from side walls."

Paragraph 52. *Capstans, winches and bitts.*—"There shall be not less than four capstans on each side wall and the necessary capstans or winches for handling moorings. There shall be not less than eight bitts on each side wall."

Paragraph 53. *Moorings.*—"Two sets of moorings shall be provided at each corner of the dock."

Paragraph 54. *Runways and shoring stages.*—"Two lines of runway and shoring stages not less than 36 inches wide shall be provided on the inner side of each side wall, and a runway about 2 feet above the main deck."

Paragraph 55. *Ladders and steps.*—"Access shall be had to the runways and shoring stages by suitable ladders and steps from the top of side walls and main deck."

Paragraph 56. *Fenders.*—"All parts of the dock liable to be fouled by a ship in docking shall be fitted with heavy rubbing timbers and fenders, so arranged as to not injure the dock if carried away and to be readily replaceable. The exterior of the dock shall be fitted with timbers and rubbing fenders as a protection from drift and fouling."

Paragraph 57. *Fire service.*—"A fire service and washing-down system shall be provided the entire length of each side wall at or near the top, and with not less than four hose connections on each side."

Paragraph 58. *Indicator system.*—"The dock shall be fitted with a reliable pneumatic or hydraulic indicator system to show the depth of water in all compartments at all times."

Paragraph 59. *Levels aud gauges.*—"The dock shall be fitted with levels and gauge boards to indicate the trim."

Paragraph 60. *Height of self-docking.*—"When self-docked, all under-water portions shall be raised to a clear height of not less than 5 feet, and shall be safely and readily accessible for inspection, painting and repairs."

Paragraph 61. *Self-docking connections.*—"With the dock at light-draught line, all self-docking and strain transmission connections shall be above water."

Paragraph 62. *Power.*—"The dock shall be operated by steam power, and shall be fitted with the necessary boilers, engines, pumps, feed-water heaters, steam separators and other accessories desirable to make a first-class self-contained plant."

Paragraph 63. *Boilers and engines.*—"There shall be not less than 600 nominal horsepower of boilers and engines suitably distributed to give the best results. Simplicity and certainty of action and freedom from possible breakdowns in operation are to be given the first consideration. Engines of a type and style which will produce the least vibration in the side walls are desired."

Paragraph 64. *Main pumps.*—"If of the centrifugal variety, the main pumps shall have a discharge of not less than 16 inches, and an equivalent discharge for other varieties."

Paragraph 65. *Piping.*—"All piping shall be of ample size to supply the pumps at maximum speed, and so installed as to be readily accessible for repairs or renewal."

Paragraph 66. *Valves.*—"The piping and flow of water shall be completely controlled by a system of simple and durable bronze-mounted valves, of the wedge variety, of easy and certain operation. All valves shall be fitted with indicators."

Paragraph 67. *Fuel and water.*—"Storage shall be provided for fuel and fresh water sufficient for two complete successive dockings of the maximum load."

Paragraph 68. *Connections to ship.*—"Provision shall be made for supplying a ship in dock with water and for carrying off her waste water and sewerage."

Paragraph 69. *Machine shop.*—"A small machine shop, suitable for light repairs to the dock, shall be installed in one side wall."

Paragraph 70. *Store room and quarters.*—"Such portions of the side walls above the engine decks as are not occupied by machinery shall be fitted as store rooms, and as quarters for the dock's officers and crew, with suitable mess arrangements."

Paragraph 71. *Hatches, skylights, deadlights and ladders.*—"The side walls shall be fitted with all the necessary hatches, skylights, deadlights, ladders and other conveniences necessary or desirable."

Paragraph 72. *Lighting plant.*—"An electric-light plant shall be installed on the dock for lighting all interior working and storage compartments and with connections for portable lights on the dock."

Paragraph 73. *Ventilating system.*—"A blower system shall be installed for ventilation of all working and storage spaces and quarters in the dock."

Paragraph 74. *Time of operation.*—"The dock shall be designed to lift a load of 16,000 gross tons with a draught of 30 feet clear of the water in four hours. Lighter loads of less draught shall be lifted in a correspondingly shorter time, and the pumps shall readily operate under a head of 35 feet. The time of operation shall be reckoned from when the ship has taken the blocks and shores and pumping is commenced until the keel is out of water."

Paragraph 75. *Place of tests.*—"All docking and self-docking tests shall be made at a suitable and convenient place at or near the works of the contractor."

Paragraph 76. *Preliminary tests.*—"Preliminary tests in sinking and raising the dock shall be made by the contractor to satisfy the officer in charge that the dock is in perfect working order."

Paragraph 77. *Cruiser test.*—"The dock shall be tested in docking a cruiser furnished by the Government centrally or off line as specified."

Paragraph 78. *Battleship test.*—"The dock shall be tested in docking a battleship furnished by the Government centrally or off line as specified."

Paragraph 79. *Deflections.*—"Observations shall be made for deflections and permanent set during the dockings by specially designed instruments furnished by the contractor which will become part of the dock's outfit. In determining the final deflec-

tion allowance shall be made for permanent set and temperature deflections, and the blocking shall be straight."

Paragraph 80. *Self-docking tests.*—"The dock shall be completely self-docked upon the completion of the docking tests."

Paragraph 81. *Board of tests.*—"The tests shall be conducted by a board of naval officers appointed by the Secretary of the Navy, one of whom shall be a line officer expert in steam engineering, one a naval constructor and one a civil engineer. The dock will be carefully examined by the Board and tested for all specified requirements."

Paragraph 82. *Conduct of tests.*—"In docking naval vessels the ships shall be maneuvered, entered and placed in position in the dock by the commanding officer and the naval constructor of the Board, according to naval practice, with tugs and labor furnished by the contractor. All preparations and manipulations of the dock in testing shall be conducted by the contractor to the satisfaction of the Board. A mutual understanding and agreement shall be had between the Board and contractor preceding docking tests, to prevent accidents to the ship or dock."

Paragraph 83. *Duration of battleship test.*—"On the last test the battleship shall be carried centrally on the dock for forty-eight hours without the dock showing any undue signs of strain or fatigue."

Paragraph 84. *Condition on delivery.*—"If the dock is delivered by the contractor at Cavite, all machinery, valves, strain transmission and self-docking connections shall be put in perfect working order before the dock is turned over to the Government."

Paragraph 85. *Docking material.*—"All the necessary material and appliances needed in testing and operating the dock shall be supplied by the contractor and become part of the dock's outfit."

Paragraph 86. *Dock equipment.*—"The dock shall be provided with all conveniences for operation, manipulation and self-docking."

Paragraph 87. *Boats.*—"Two 20-foot metallic life boats with complete equipment shall be provided with the dock."

Paragraphs 88–100. Provide for the quality of materials and

their inspection. The steel is required to be open-hearth of a superior quality, and of a medium grade for the hull material and a soft grade for the rivets.

Paragraphs 101–113. Provide for the quality of workmanship and its inspection. Workmanship must be neat and workmanlike and equal to the best American ship practice.

Paragraphs 114–118. Provide for cleaning and painting metal.

Bids were asked under five items, as follows:

Item 1. For delivery at Cavite.

Item 2. For delivery at the works of the contractor insured for towing.

Item 3. For delivery at works of contractor without insurance.

Item 4. For towing to Cavite.

Item 5. For alternate proposals at the discretion of bidders.

REVIEW OF SPECIFICATION.

The specification is the most comprehensive and complete of any that has yet been issued for a floating drydock.

Heretofore the designs for floating drydocks for Naval purposes have been largely left in the hands of civilian designers whose principal business is in designing commercial docks. The English naval architects have, practically, had a monopoly of this line of naval architecture for the past twenty-five years, and such developments as have been made up to the present time have been made by them. Too much of purely commercial consideration has entered into the design of military docks. There has been an effort to secure the greatest possible dimensions and displacement with the least amount of material and call this result battleship lifting power.

The design of a military floating drydock should differ as much from that of a commercial floating drydock as the design of an armored cruiser differs from that of a transatlantic liner. The uses and purposes are as different in one case as in the other. The commercial dock deals with ships having strong bottoms, much inherent stiffness, and weights of fairly uniform distribution. The military dock deals with ships having tender bottoms, less stiffness, and great weights unevenly distributed. In the

commercial dock, original cost and interest on the investment have first consideration. In the military dock, strength, safety, durability, ease and certainty of operation, and adaptability to varying conditions take precedence over all else. A battleship is not designed to yield a certain return in money, and neither should a military dock be so designed.

The aim of the specification is apparent from the quotations previously given. In designing a floating dock, both present and future conditions must have consideration, and developments anticipated or unexpected must be provided for. In our own naval establishment a definite maximum seems to have been reached for the present. Battleships of 16,000 tons displacement and 450 feet of length, and armored cruisers of 14,500 tons displacement and 500 feet in length will apparently be our standard for some years to come, and it is an open question among naval experts whether future conditions will increase or diminish these figures. Radius of action, accessibility to all ports of commercial or strategic importance, improvements in arms, armament and machinery, speed, and durability in action are some of the factors influencing the dimensions and displacement of a fighting ship. The present specification provides for a floating dock which will not only take with ease all our present naval vessels, but will also safely dock a battleship of 20,000 tons displacement, or an armored cruiser of 600 feet in length. In the present specification the draught of the dock has had especial consideration. An ordinary working draught of 30 feet has been provided with an 8-foot freeboard of the side walls, and it has been further provided that the pumps shall readily operate under a head of 35 feet. This would, in emergency, allow a draught over the keel blocks of 36 feet.

A draught of 30 feet is a liberal estimate for future warships. A military dock, however, may be called upon to deal with ships considerably down by the head or stern, or badly listed, and ample provision has been made for such contingencies.

The limits of stress and deflection and the uniform pumping and lifting capacity provided in the specification will give a dock

in which a ship may be docked in the end, or in which the ship may be straightened or hogged as required, by regulating the water load in the compartments of the dock. The value of these conditions for many repairs to hull and machinery is very great.

The equipment of the dock as to the conveniences for operation for the safe and convenient docking of vessels has been made full and complete.

The preservation of a large steel floating drydock necessitates that it shall be self-docking. They are far too large to enter a graving dock, and, even if it were possible, they are frequently located where no graving docks exist or are possible. For the greatest safety in docking a war vessel, a floating dock should be as nearly continuous and solid as possible. For self-docking, it must be separable into parts which will dock each other, thus permitting each section to be repaired when necessary.

The problem, then, which confronts the floating-dock designer is to produce a structure which is practically solid and continuous in docking operations, but which can still be separated into parts and self-docked. The specifications have left the self-docking feature entirely free to designers, requiring only a safe and convenient height in self-docking and a limit of stress on material.

## THE BIDS.

Bids on competitive designs under the general specification were received by the Bureau of Yards and Docks, Navy Department, on March 14, 1903.

Mr. Chauncey N. Dutton, Engineer, submitted bids on a modification of his pneumatic lift-lock system. The apparatus, while of great merit, provided a stationary instead of a movable dock, and placed the responsibility of foundations on the Government.

The United States Shipbuilding Company submitted bids on a Rennie type of dock, as follows:

For delivery at the Cavite Naval Station, to be constructed at San Francisco and towed out, or erected and launched at the Cavite station, in the discretion of the bidders, $1,443,000.

For delivery to the Government at San Francisco, uninsured, $1,220,000.

For delivery to the Government on the Atlantic Coast, uninsured, $1,184,000.

For delivery to the Government at Cavite Station, "knocked down," and to be erected and launched by the Government, $1,100,000.

The Maryland Steel Company submitted bids on a Clark type of dock, on a type proposed by Civil Engineer A. C. Cunningham, U. S. N., and on a type of their own design, as follows:

Clark type, delivered on the Atlantic Coast, uninsured, $1,215,000. The general plan of the design is shown in the sketches accompanying the description of the dock.

Cunningham type, delivered on the Atlantic Coast, uninsured, $1,164,000.

Maryland Steel Company type, delivered on the Atlantic Coast, uninsured, $1,124,000.

Cunningham type, in 452 feet length, delivered on the Atlantic Coast, uninsured, $1,085,000.

### THE AWARD.

On April 9, 1903, the contract was awarded to the Maryland Steel Company on their own design at the price bid.

### THE DESIGNS.

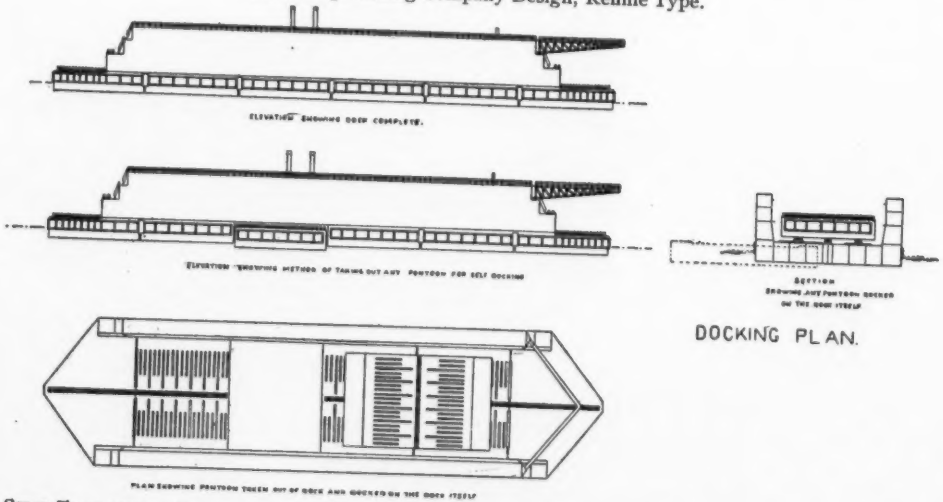
The design of Mr. Dutton not being for a floating dock will not be reviewed here.

### U. S. SHIPBUILDING COMPANY'S DESIGN.

The design is on the Rennie type of dock, and was made for the bidders by Stevenson & Company of England. It is well illustrated in the accompanying plates. This type of dock was proposed by Rennie, the English drydock expert, many years ago. It was well suited to its time when ships were much shorter and stiffer than they now are, and had much less heavy and concentrated loads. As a military dock it has

PROPOSED SELF-DOCKING STEEL FLOATING DRYDOCK FOR U. S. NAVAL STATION, CAVITE, PHILIPPINE ISLANDS.

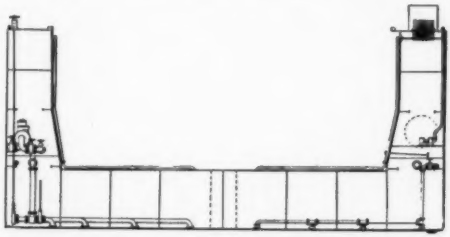
U. S. Shipbuilding Company Design, Rennie Type.




SIDE ELEVATION, PLAN AND END ELEVATION, SHOWING METHOD OF SELF-DOCKING A PONTOON.

passed its period of usefulness. It is dependent upon its side walls almost entirely for longitudinal stiffness on account of its numerous transverse pontoons. The pumps are located undesirably high for certainty of action in removing the last of the water from the pontoons.

This type of dock is not regarded with favor for towing long distances, as it has little resistance to torsion, and is easily twisted in a sea way. Self-docking in a strong tide or current is not easy on account of the pontoon coming out sideways from under the walls. When one or more intermediate pontoons are detached this type of dock must be handled with the greatest care, as there is then a long unsupported reach of side walls which is easily buckled or broken by uneven pumping of the remaining pontoons, or even from a heavy swell of the sea.



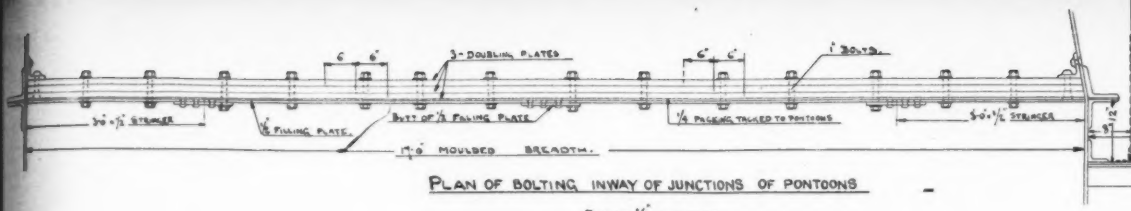
U. S. SHIPBUILDING CO. DESIGN, RENNIE TYPE.

Cross section showing piping.

MARYLAND STEEL COMPANY'S DESIGNS.

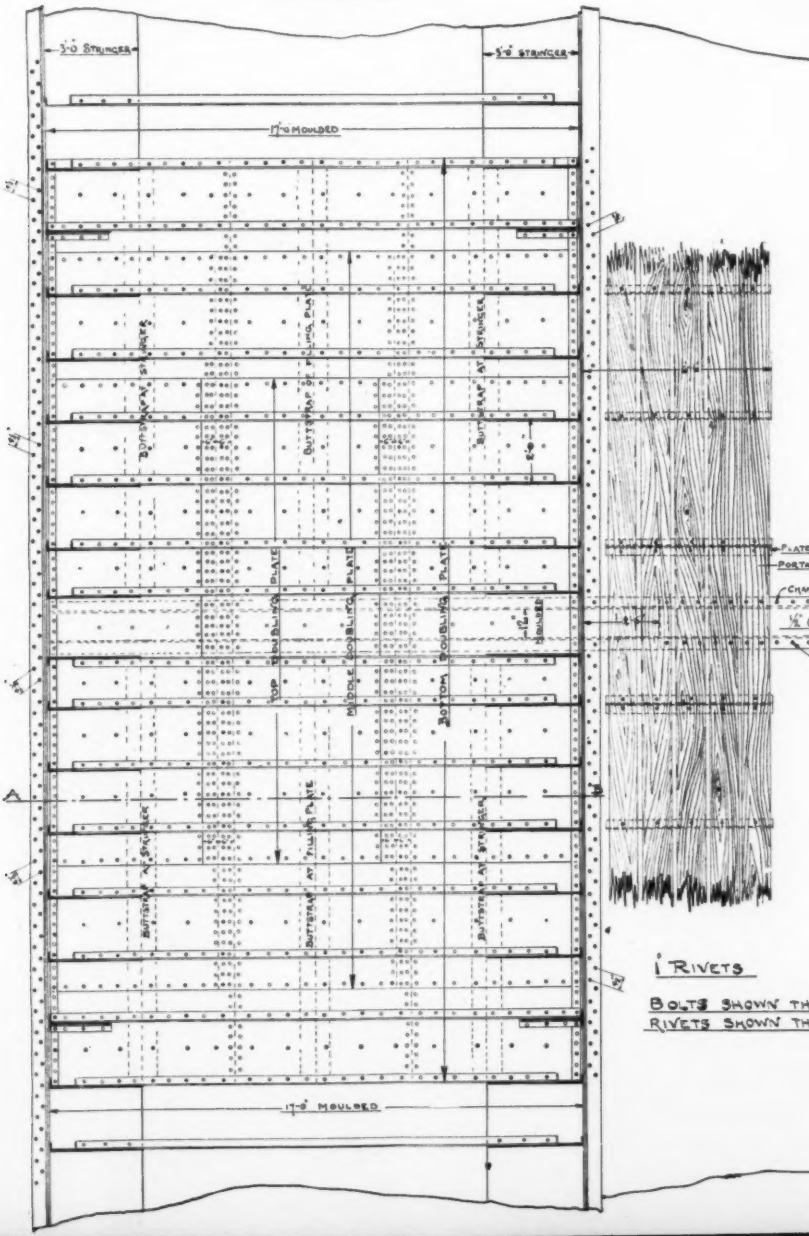
*The Clark Type.*— This design was made for the Maryland Steel Company by Mr. Lyonel Clark, of London, whose design for the New Orleans military dock was described in the preceding issue of this JOURNAL.

This design is the best of its type yet produced by Mr. Clark. The submerged joints have been brought above the water line, and in nearly every particular the specified requirements have been met. The altars, which are necessitated by the upper connections, considerably reduce the area of the working deck, and narrow its clearance for a considerable height above the block-




PLAN OF BOLTING INWAY OF JUNCTIONS OF PONTOONS

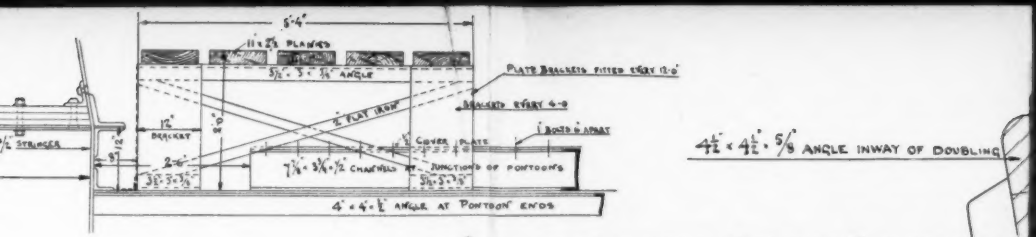
SCALE ½ = 1 FOOT




1" RIVETS

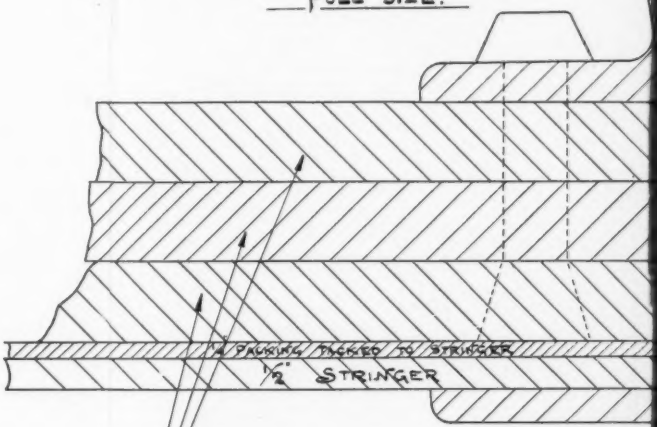
BOLTS SHOWN TH

RIVETS SHOWN TH


5'-4"
11 x 2½ PLANKS
5½" x 3" x ½" ANGLE
PLATE BRACKETS FITTED EVERY 12-0"
BRACKETED EVERY 4-0
2" FLAT IRON
12" BRACKET
½" COVER PLATE
1 BOLT 6 APART
7⅞" x ¾" x ½" CHANNELS AT JUNCTIONS OF PONTOONS
4" x 4" x ½" ANGLE AT PONTOON ENDS

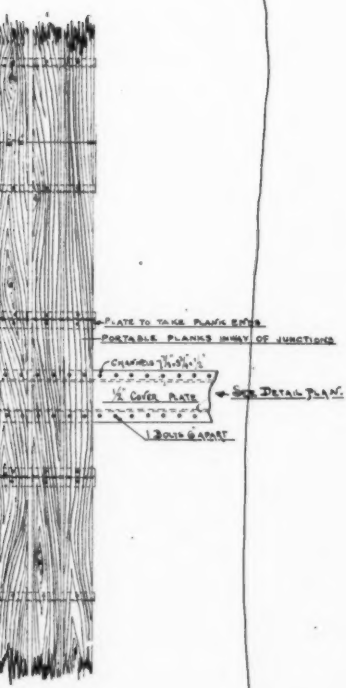
4½" x 4½" x ⅝" ANGLE INWAY OF DOUBLING

SKETCH SHEWING CONNECTION OF PONTOONS TO SIDE GIRDERS AT Nos 3 & 4 PONTOONS
FULL SIZE.




5½" x 5" x ½" ANGLE

DOUBLINGS DECREASED IN THICKNESS AT Nos 1 & 2 & 5 & 6 PONTOONS IN ACCORDANCE WITH REDUCED STRAIN.




½ BULKHEAD IN PONTOO

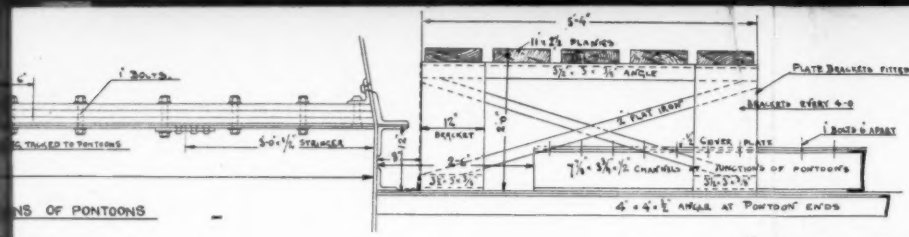
RIVETS

LTS SHOWN THUS •
ETS SHOWN THUS ○

PROPOSED SELF-DOCKING STEEL FLOATING DRYDOCK FOR U. S. NA STATION, CAVITE, PHILIPPINE ISLANDS.

U. S. Shipbuilding Company Design, Rennie Type.

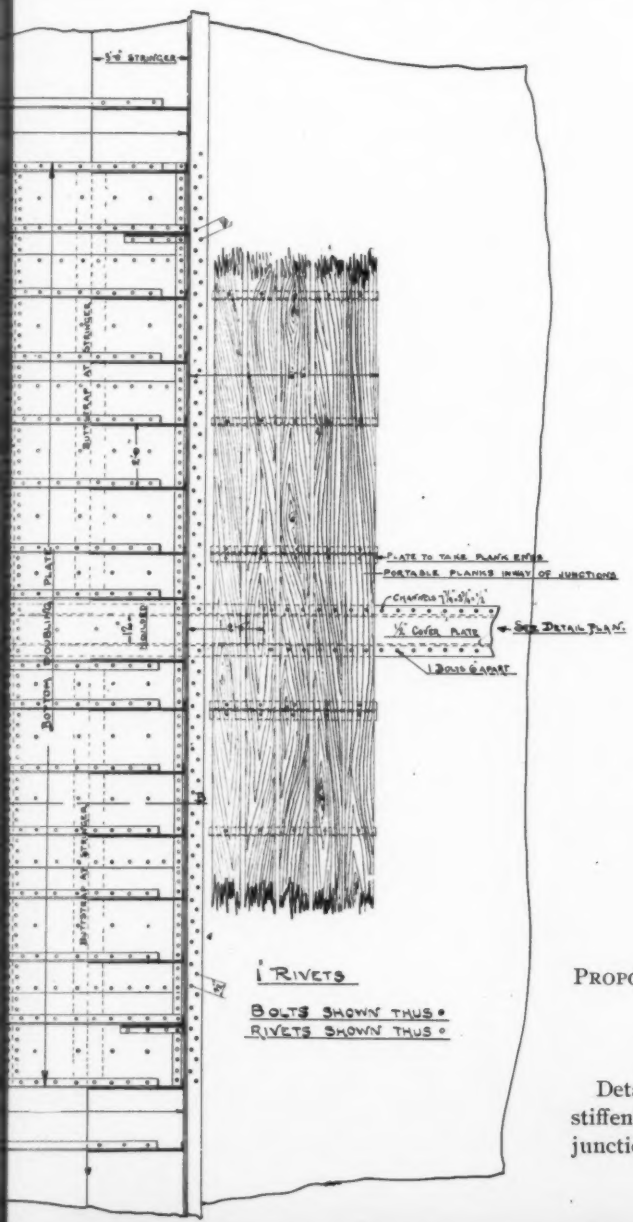
Details of connections between pontoons and side walls, and metho stiffening bottom chord of side wall at junction of pontoons. All bolts junction surfaces are made watertight with packing and white lead.

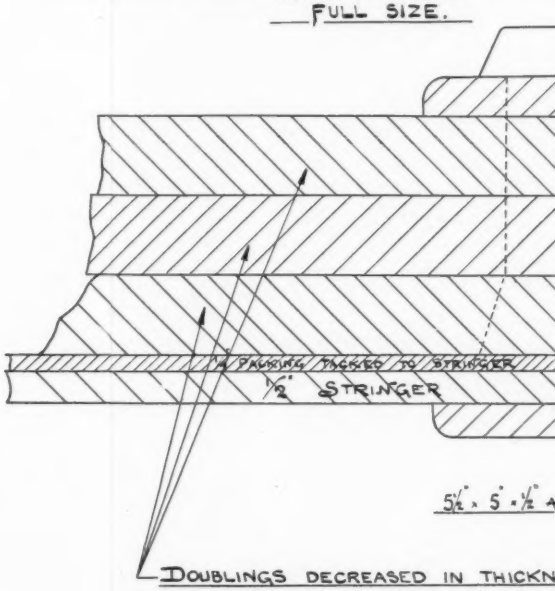

1" Bolts
5'-4"
1½" Planks
5½" × 3½" × ⅞" Angle
Plate Bracketed fitted every 12-0
Bracketed every 4-0
12" Bracket
2" Flat Inway
1" Bolts 6" apart
⅝" Cover Plate
7⅞" × 5⅜" × ½" Chamfered at Junctions of Pontoons
3½" × 3½" × ⅝"
4" × 4" × ½" Angle at Pontoon Ends
5'-0" × ½" Stringer

4½" × 4½" × ⅝" Angle inway of

NS OF PONTOONS

Sketch shewing connection of Pontoons to Sid
at Nos 3 & 4 Pontoons
FULL SIZE.




5½" × 5" × ½" A

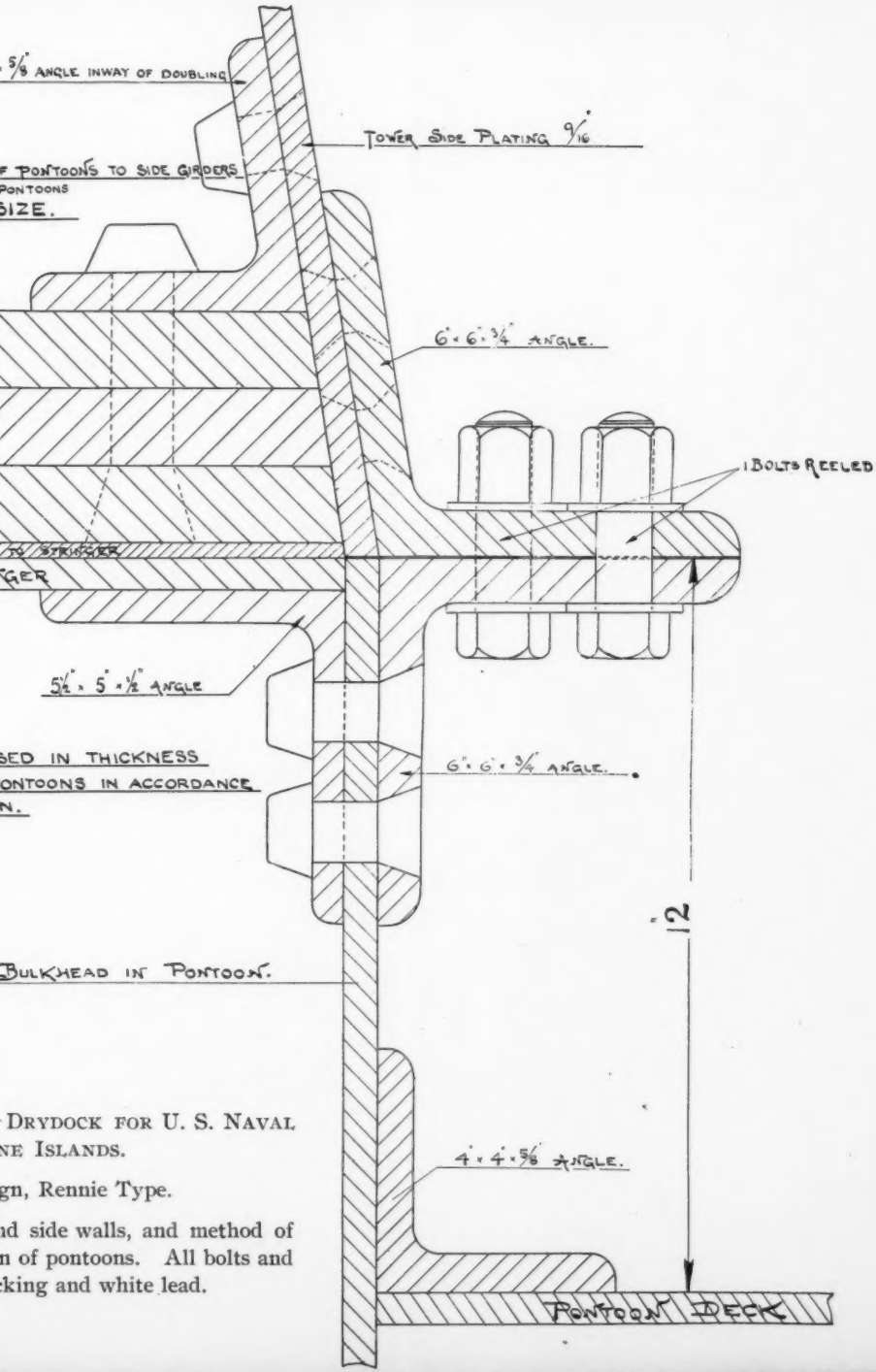
Doublings decreased in thickn
at Nos 1 & 2 & 5 & 6 Pontoons in acc
with reduced strain.

½ Bulkhead in

Proposed Self-Docking Steel Floating Drydock for
Station, Cavite, Philippine Islands.

U. S. Shipbuilding Company Design, Rennie Typ

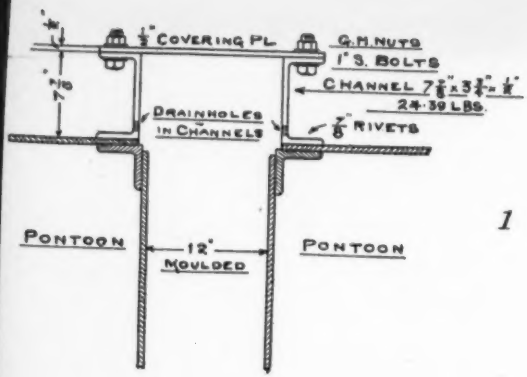
Details of connections between pontoons and side walls, a
stiffening bottom chord of side wall at junction of pontoons.
junction surfaces are made watertight with packing and white




DRYDOCK FOR U. S. NAVAL
NE ISLANDS.

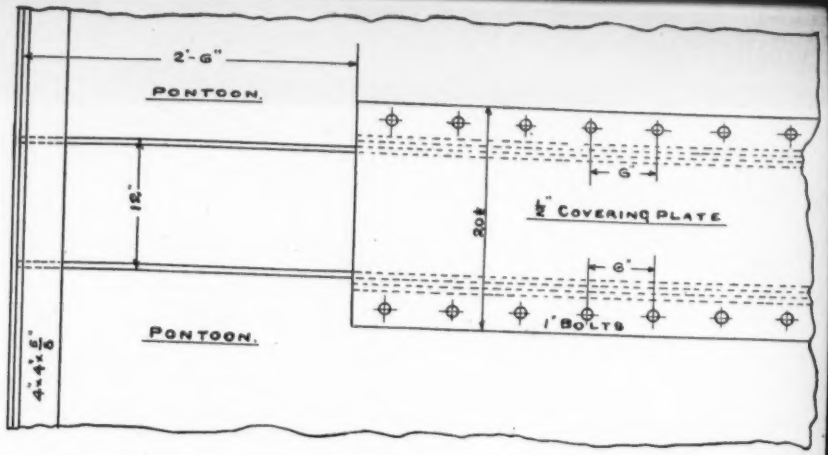
gn, Rennie Type.

ad side walls, and method of
n of pontoons. All bolts and
cking and white lead.

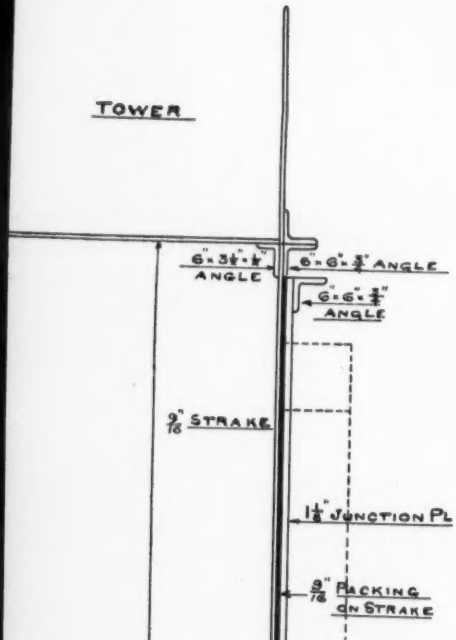



1

TOWER

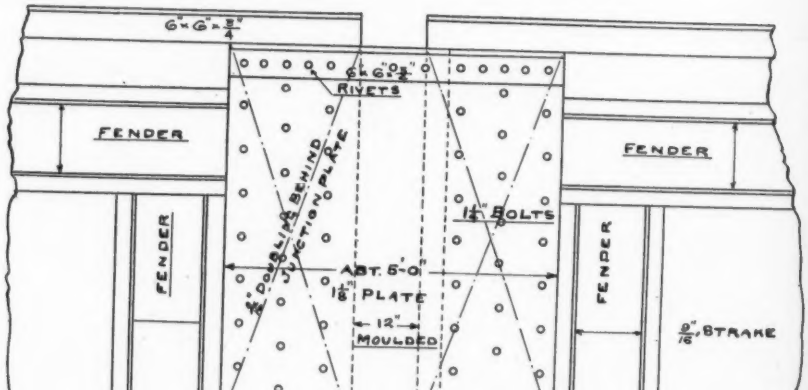


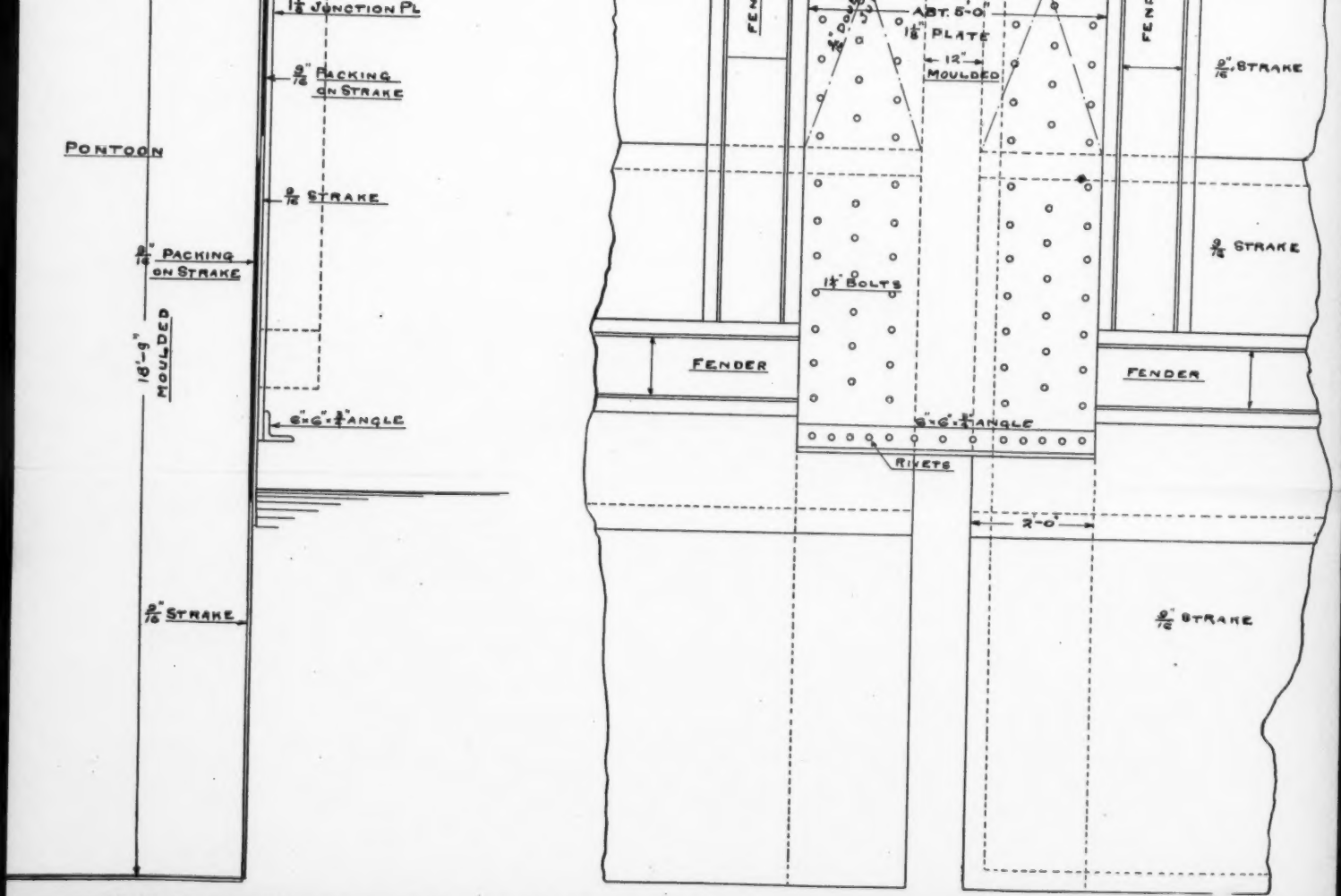

TOWER



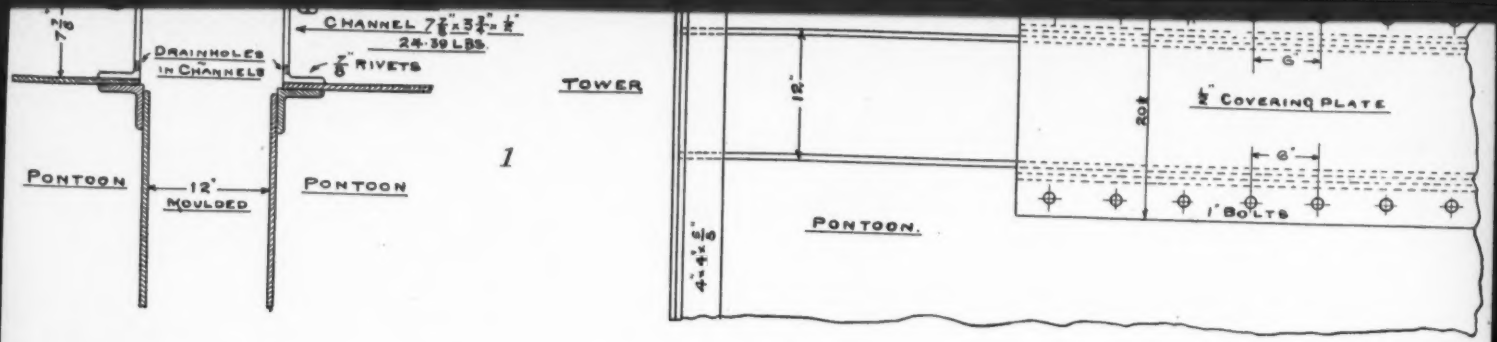

2

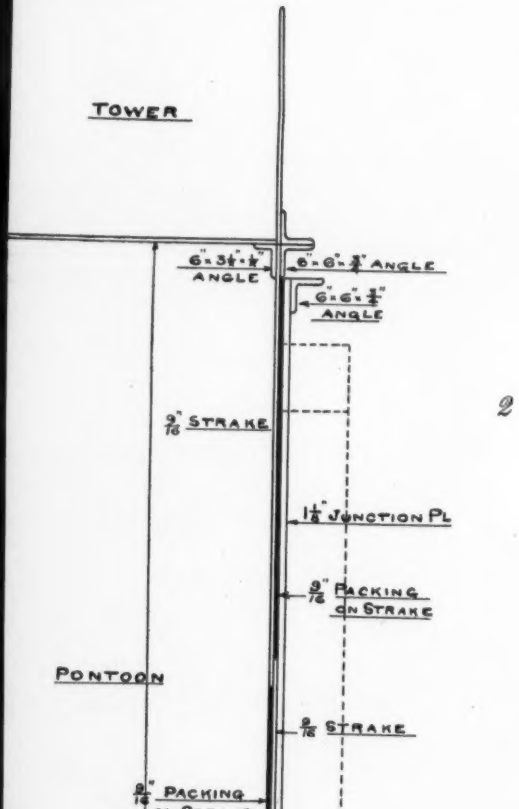
STIFFENING PLATE FOR
PONTOON JUNCTION
SCALE ¾" = 1 FOOT



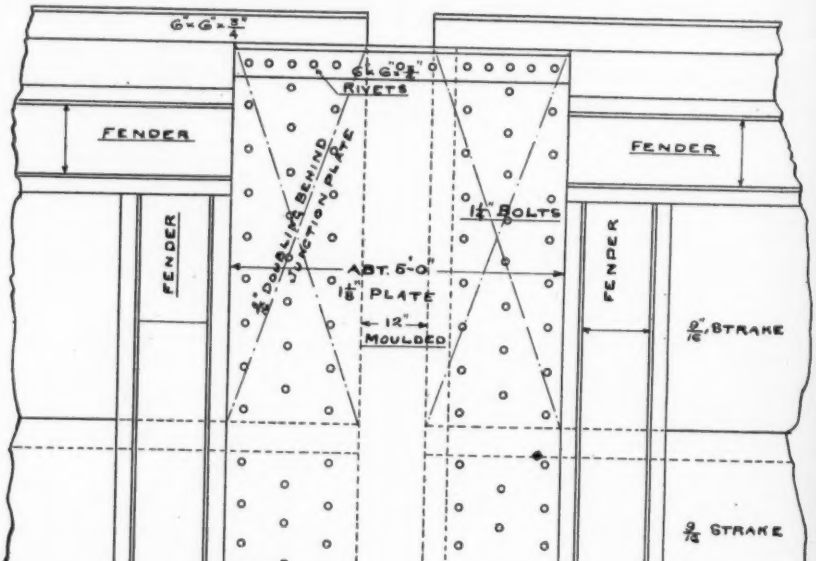


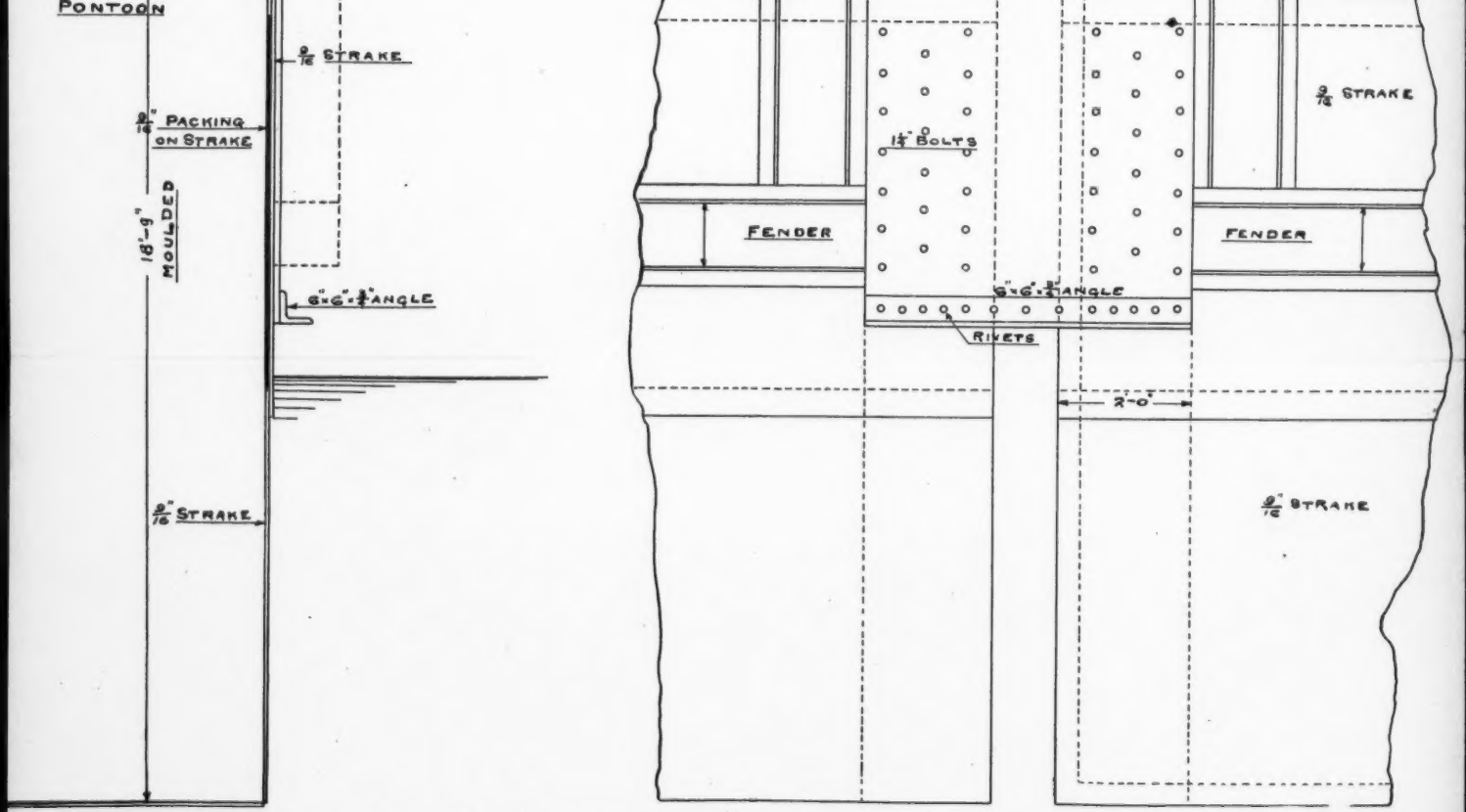

PROPOSED SELF-DOCKING STEEL FLOATING DRYDOCK FOR U. S. NAVAL STATION, CAVITE, P. I.




STIFFENING PLATE FOR
PONTOON JUNCTION
SCALE ¾"=1 FOOT



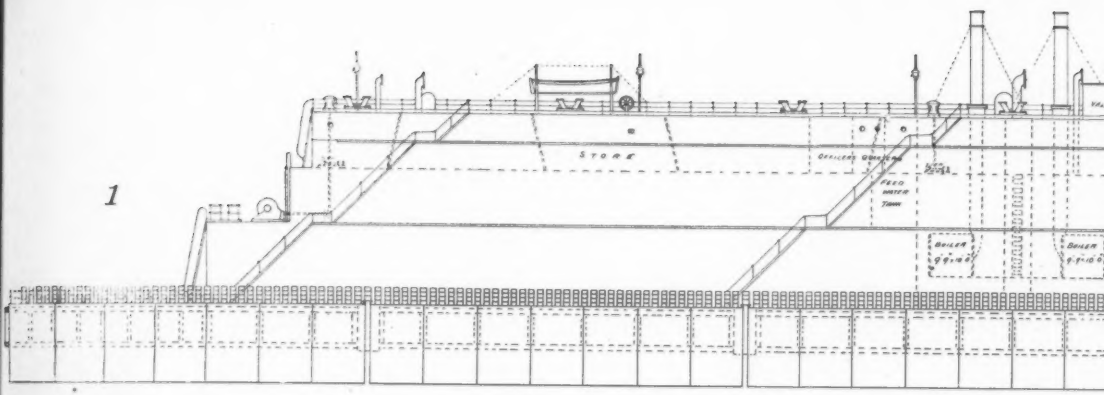



PROPOSED SELF-DOCKING STEEL FLOATING DRYDOCK FOR U. S. NAVAL STATION, CAVITE, PHILIPPINE ISLANDS.

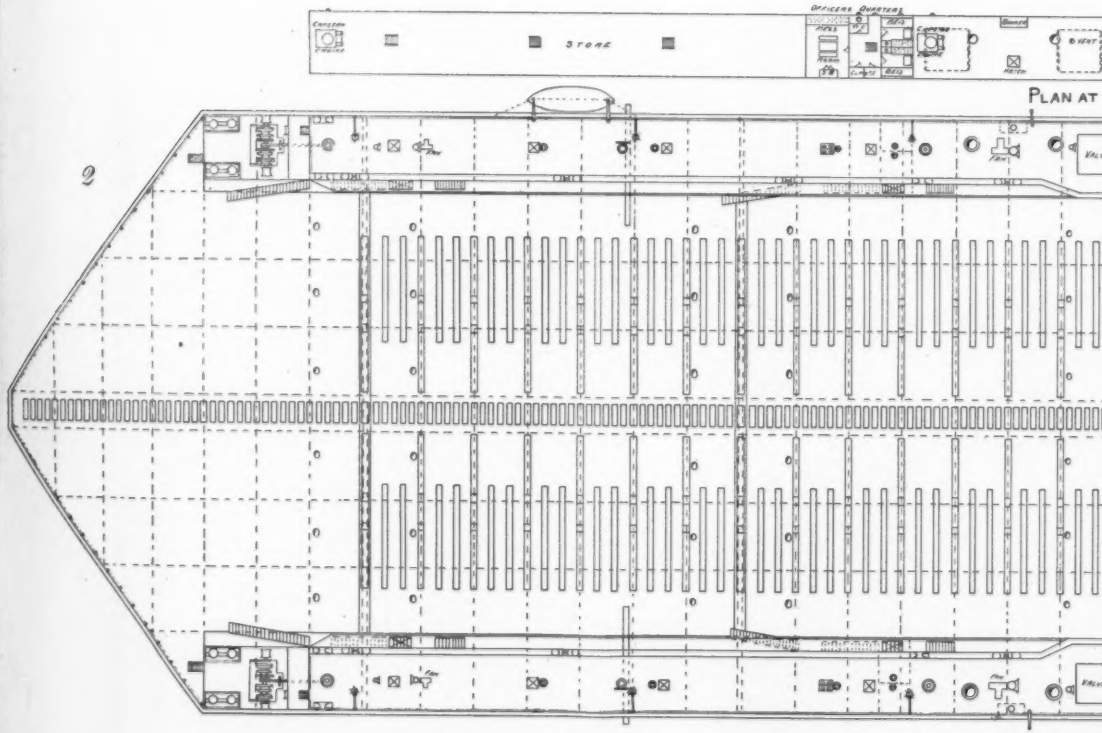
U. S. Shipbuilding Company Design, Rennie Type.

(1) Connection between pontoons over working deck. The cover plate carries a block sill.

(2) Section and side view of connection plate on outside of pontoons. The bolts pass through the skin of pontoon and are made watertight with grommets and white lead.




SECTIONAL



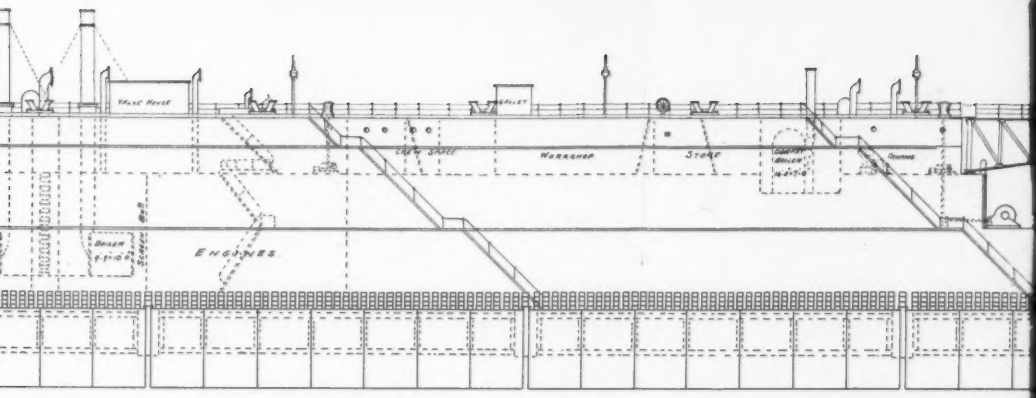

PLAN AT

F

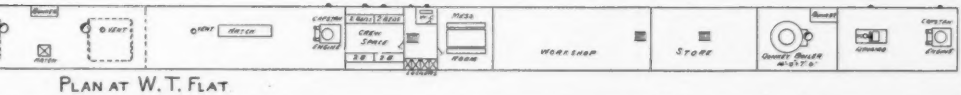
PROPOSED SELF-DOCKING STEEL FLOATING DRYDOCK F

United States Shipbuilding C

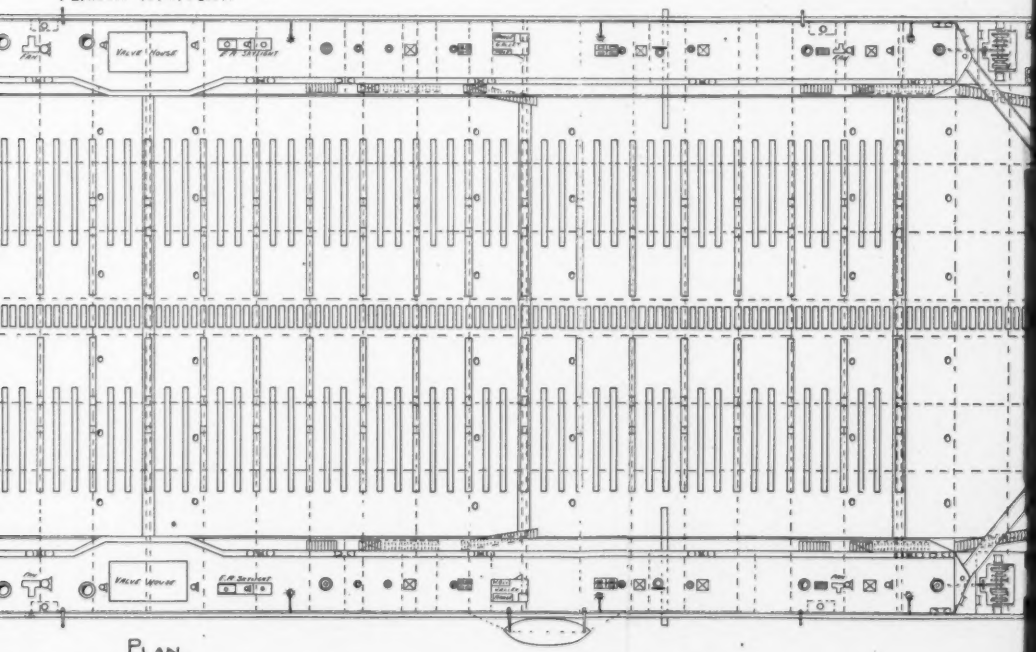
(1) Sectional elevation through pontoons, showing port side wall from inboard, starboard side w
(2) Plan of dock showing general distribution of machinery in side walls and location of blockin




SECTIONAL ELEVATION.




PLAN AT W. T. FLAT



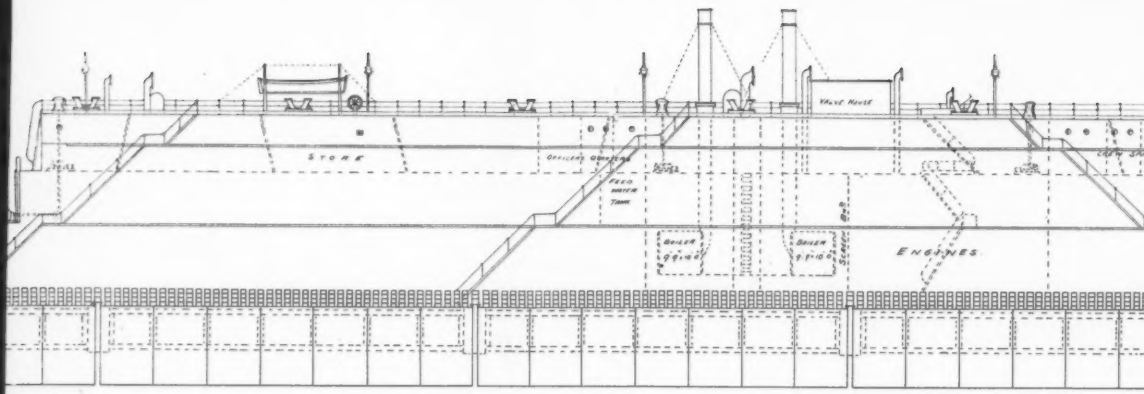

PLAN.

DRYDOCK FOR U. S. NAVAL STATION, CAVITE, PHILIPPINE ISLANDS.

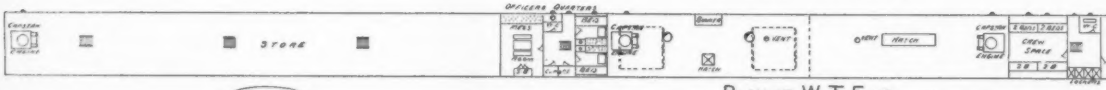
ipbuilding Company Design, Rennie Type.

rboard side wall removed. The side walls are similar.

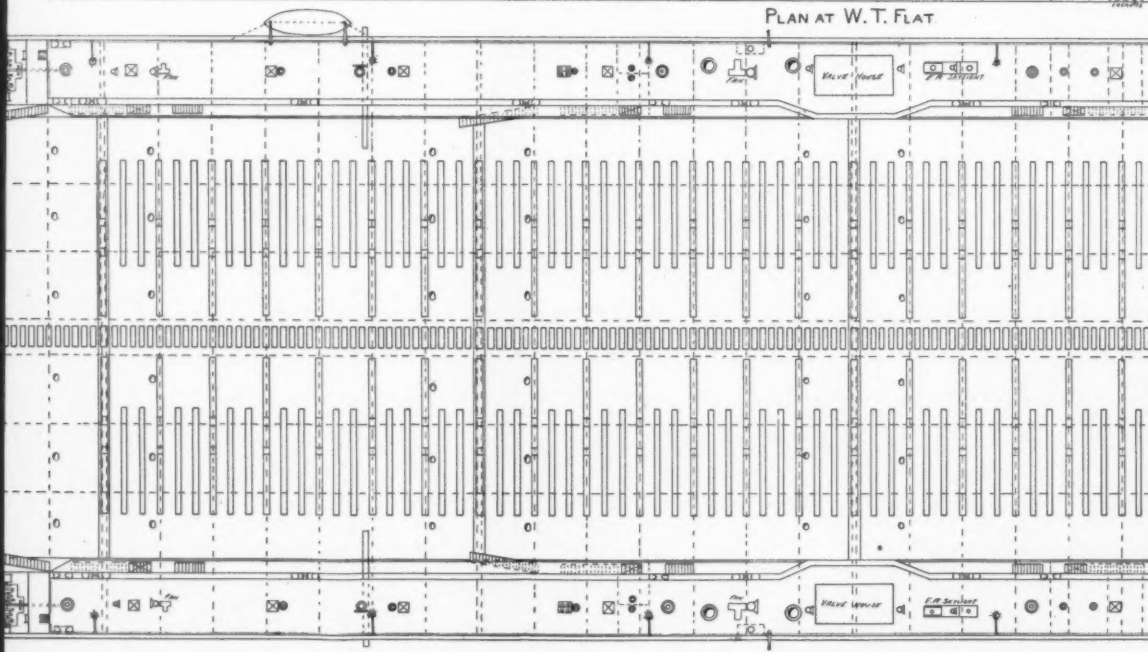
ion of blocking and sills on decks of pontoons. Location of girders and bulkheads indicated by do




SECTIONAL ELEVATION.




PLAN AT W. T. FLAT

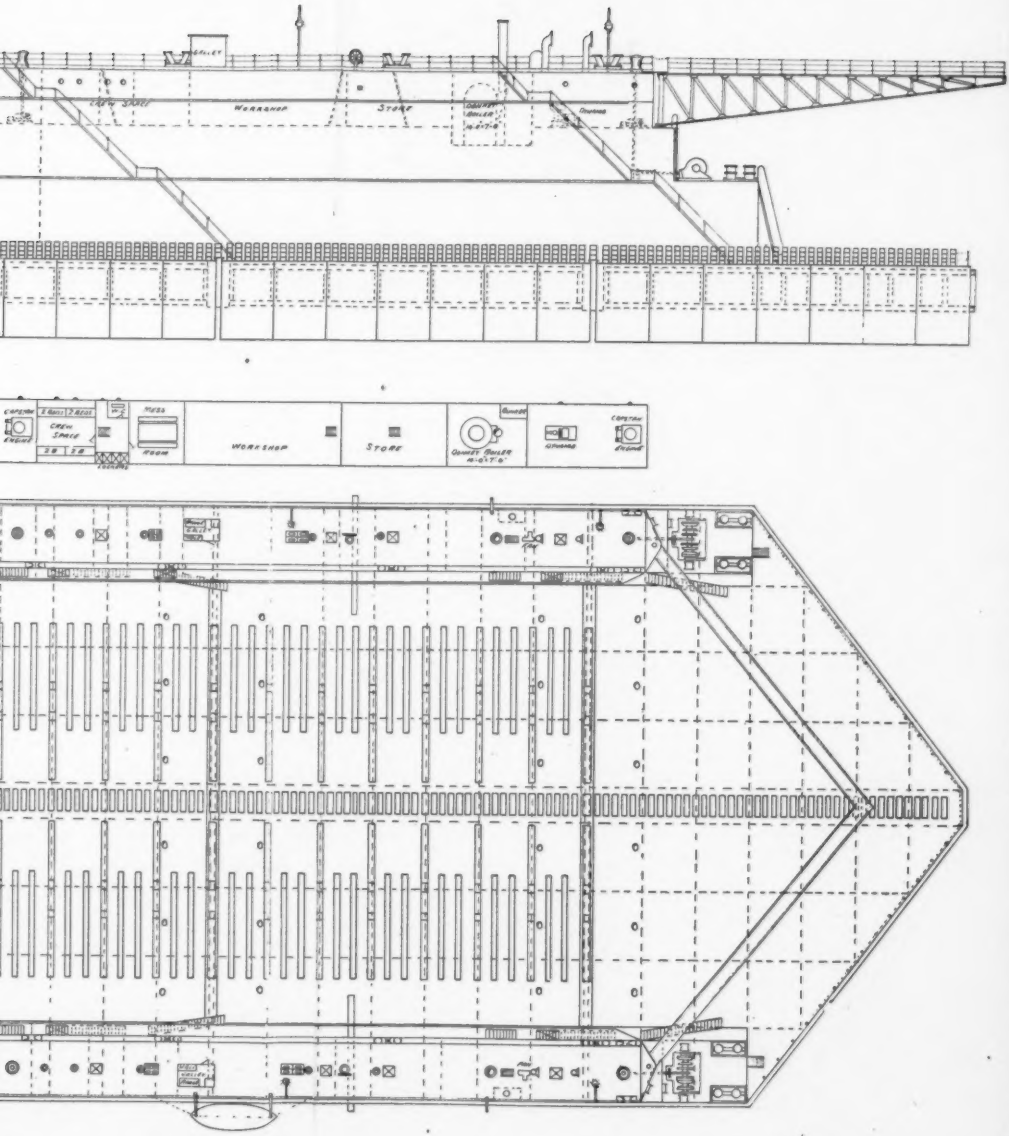



PLAN.

PROPOSED SELF-DOCKING STEEL FLOATING DRYDOCK FOR U. S. NAVAL STATION, C

United States Shipbuilding Company Design, Rennie Type

levation through pontoons, showing port side wall from inboard, starboard side wall removed. The side walls
ck showing general distribution of machinery in side walls and location of blocking and sills on decks of ponto

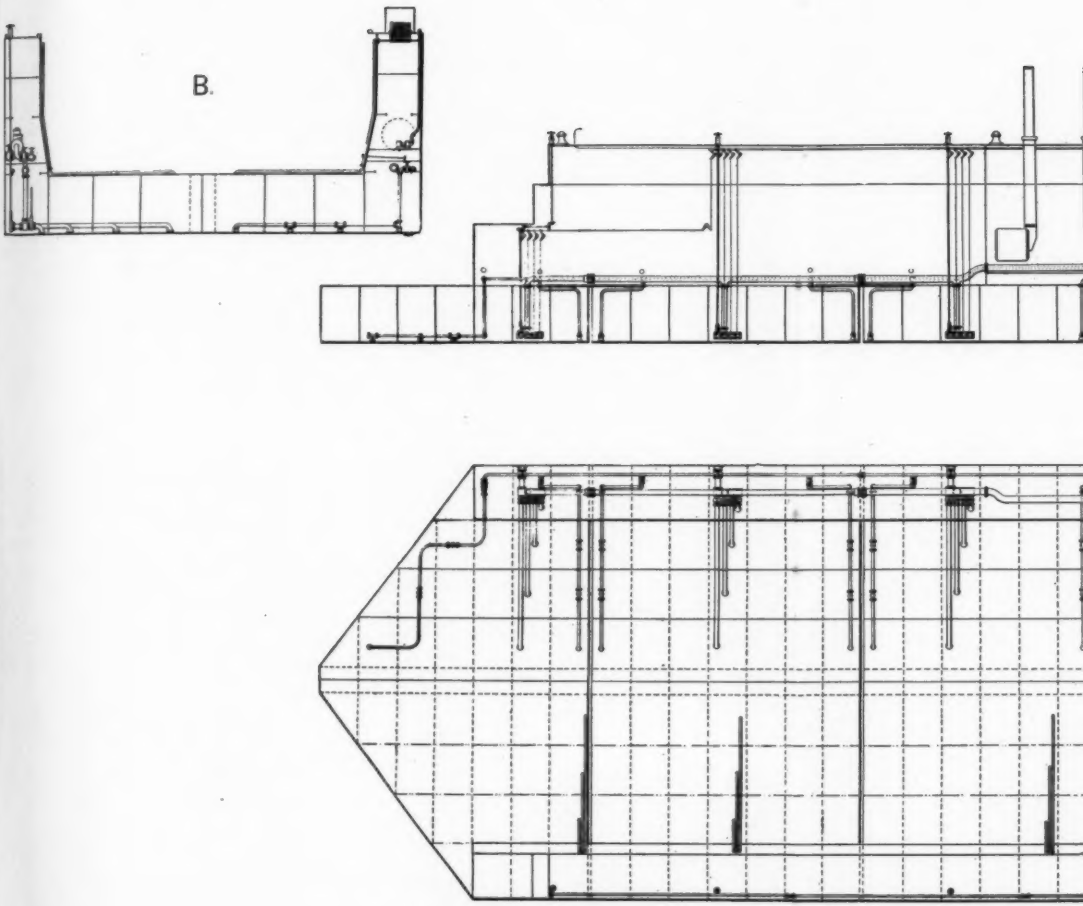



STATION, CAVITE, PHILIPPINE ISLANDS.

Rennie Type.

he side walls are similar.

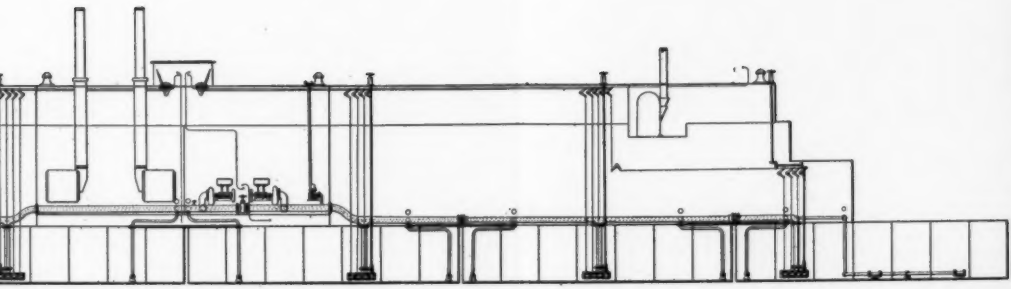
cks of pontoons. Location of girders and bulkheads indicated by dotted lines.

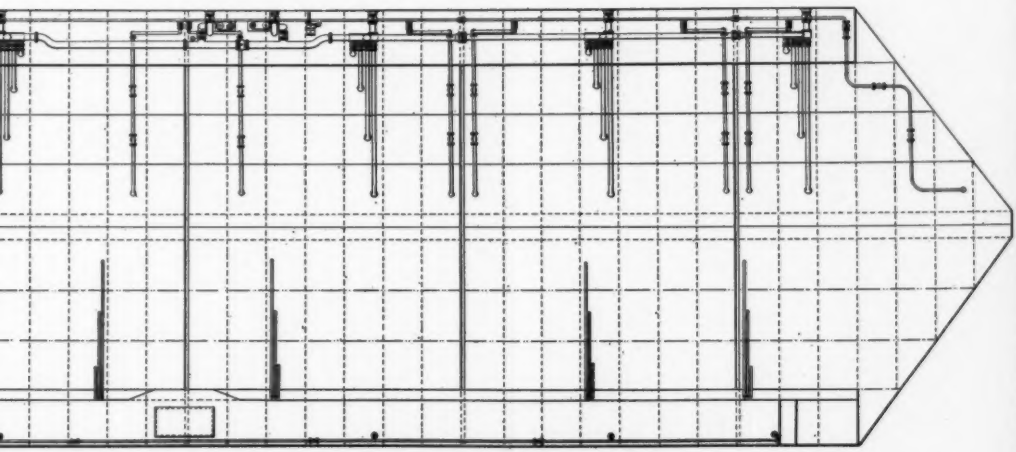



PROPOSED SELF-DOCKING STEEL FLOATING DRYDOCK FOR U. S. N

U. S. Shipbuilding Design, Ren

Cross sectional elevation, side sectional elevation and sectional plan, showing location of machinery each side of the dock. In the cross section the main pipes are shown on one side and the drainage pipes the air pipes on the other.





FOR U. S. NAVAL STATION, CAVITE, PHILIPPINE ISLANDS.

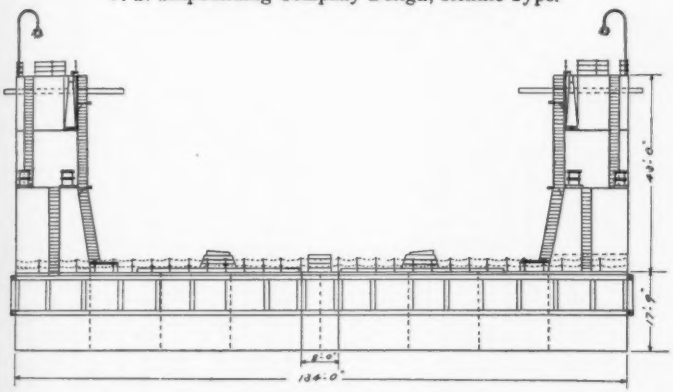
Design, Rennie Type.

of machinery and pumps and arrangement of piping and valves. The installation is similar on
rainage pipes on the other. In the plan the main and drainage pipes are shown on one side and

ing. The pumps are, necessarily, placed higher than desirable, and in securing the specified self-docking of the side walls the dock is canted to a very undesirable angle, and a portion of the main deck is submerged. The self-docking of the pontoons in

PROPOSED SELF-DOCKING STEEL FLOATING DRYDOCK FOR U. S. NAVAL STATION, CAVITE, PHILIPPINE ISLANDS.

U. S. Shipbuilding Company Design, Rennie Type.




END ELEVATION.

RENNIE TYPE OF DRYDOCK.

Swinging bridges open, showing system of fenders around body of dock, and arrangement of ladders and location of towing bitts.

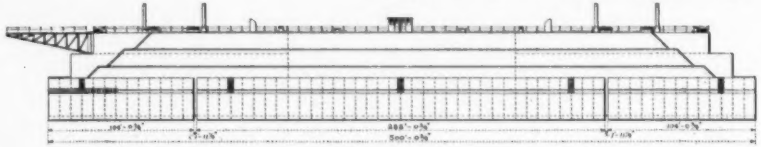
this type is also illustrated in the preceding number of this JOURNAL. Other modifications of this dock are as shown by the plans, which are from the designs for a dock constructed by Mr. Clark for a foreign government.

*The Cunningham Type.*—This design was made by the Maryland Steel Company on a type proposed by the author of this paper. It is well illustrated by the titles and sketches, which are sufficiently complete to point out their distinctive features in the accompanying plates.

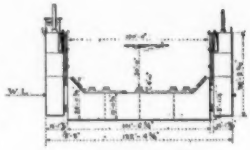
In this design the bidders state in their detailed specification as follows:

PROPOSED SELF-DOCKING STEEL FLOATING DRYDOCK FOR U. S. NAVAL STATION, CAVITE, PHILIPPINE ISLANDS.

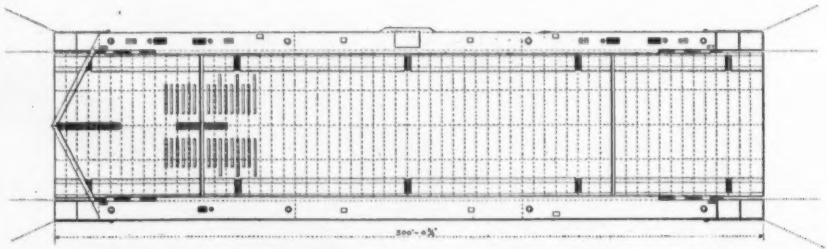
Clark Type, Maryland Steel Company Design.



SIDE ELEVATION
(PORT WALL REMOVED)



END ELEVATION.

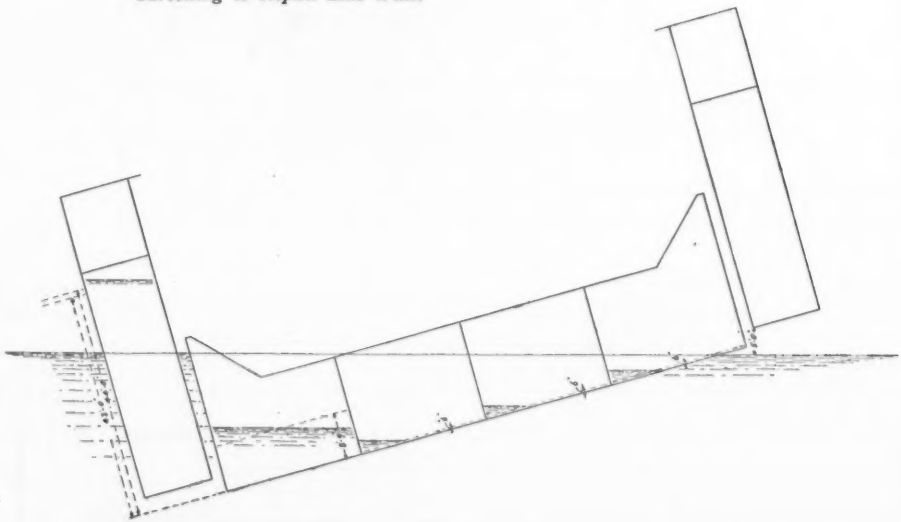


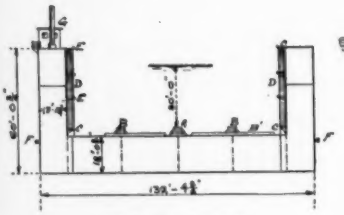
Showing location of machinery in ends of starboard side wall and distribution of bulkheads and girders.

PROPOSED SELF-DOCKING STEEL FLOATING DRYDOCK FOR U. S. NAVAL STATION, CAVITE, PHILIPPINE ISLANDS.

Clark Type, Maryland Steel Company Design.

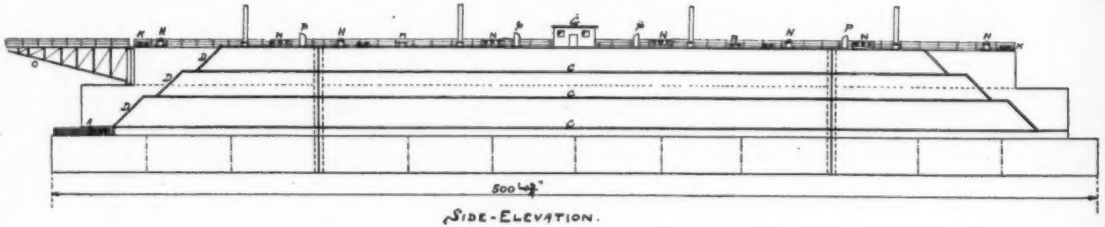
*Careening to Repair Side Wall.*



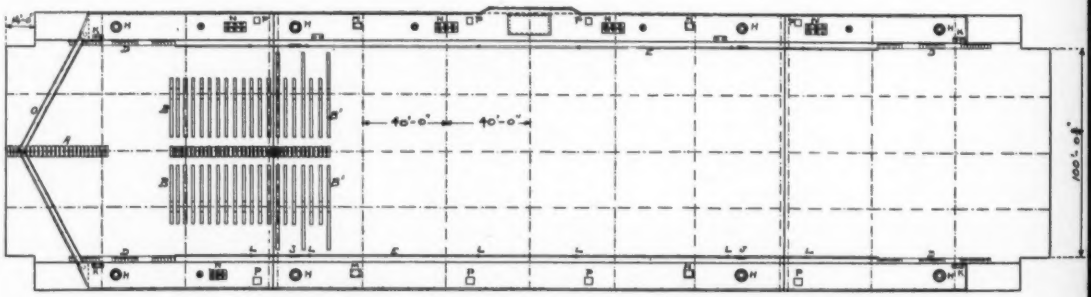



END-ELEVATION

Showing position of machinery on starboard side wall and end narrowed for self-docking.




SIDE-ELEVATION.
(PORT WALL REMOVED)

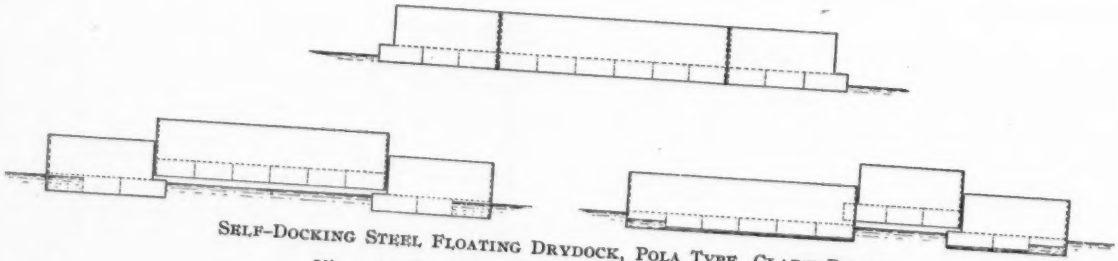



SELF-DOCKING STEEL FLOATING DRYDOCK, POLA TYPE, CLARK DESIGN.

Side elevation and plan showing location of machinery in starboard side wall, junction of sections, and location of bulkheads. On the end sections the side walls are set back and the ends narrowed for self docking.

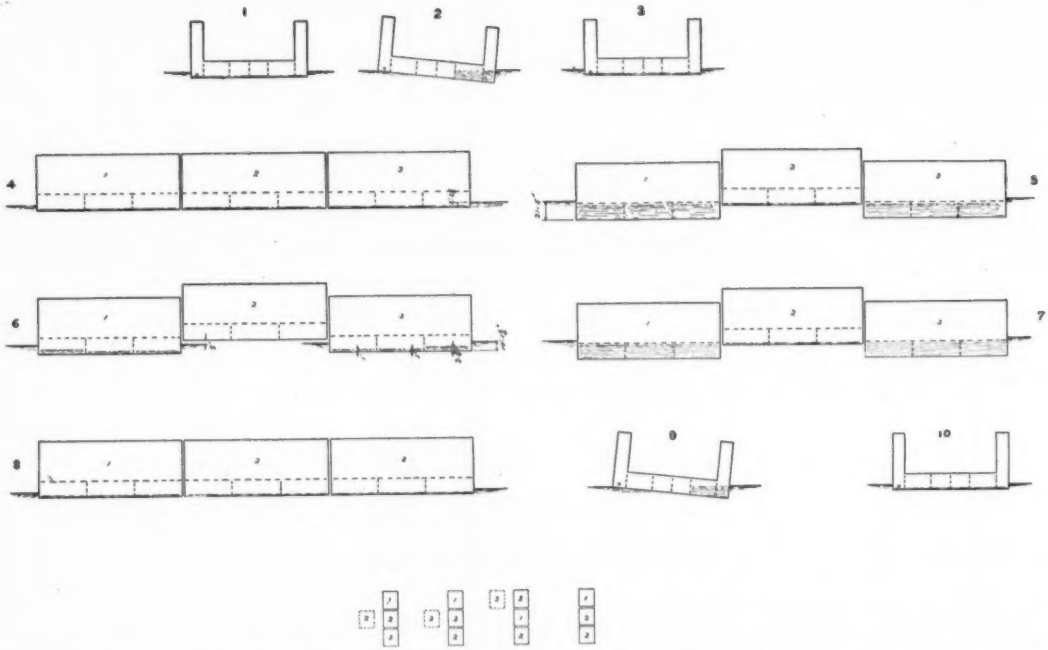
SELF-DOCKING STEEL FLOATING DRYDOCK, POLA TYPE, CLARK DESIGN.

Side elevation and plan showing location of machinery in starboard side wall, junction of sections, and location of bulkheads. On the end sections the side walls are set back and the ends narrowed for self docking.



SELF-DOCKING STEEL FLOATING DRYDOCK, POLA TYPE, CLARK DESIGN.

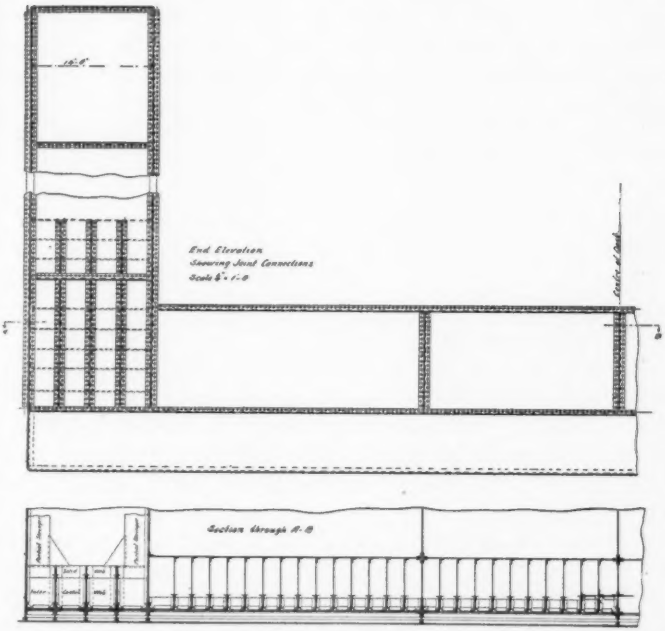
Views showing self-docking of center and end sections.




PROPOSED SELF-DOCKING STEEL FLOATING DRYDOCK FOR U. S. NAVAL STATION, CAVITE, PHILIPPINE ISLANDS.

Maryland Steel Company Design, Cunningham Type.

Showing Method of Self-Docking and Shifting Position of Sections.




PROPOSED SELF-DOCKING STEEL FLOATING DRYDOCK FOR U. S. NAVAL STATION, CAVITE, PHILIPPINE ISLANDS.

Maryland Steel Company Design, Cunningham Type.

Half end view of dock section showing connection for bolts, and section through same showing manner of bracketing back into body of dock.

GENERAL DESCRIPTION.

"The dock will be a self-docking, floating steel structure, composed of side walls and pontoons, with a general ⌊⎽⎽⌋ shaped cross section, divided into three sections and fifty-four watertight compartments, and so arranged that each section can be readily self-docked by means of the others without the aid of auxiliary constructions.

"The dock will have a total length of 500 feet, a clear width between fenders on side walls of 100 feet, and a freeboard of 11 feet with 30 feet of water above the keel blocks.

Showing Method of Self-Docking and Shifting Position of Sections.

"The lifting capacity will be 16,000 gross tons, or 32 tons per running foot over the entire length of the dock, with main deck 2 feet above water line and 1 foot of water remaining in all compartments.

"It will be divided into three uniform sections, strongly bolted together, and each section will be independent and contain its own operating machinery. Each pontoon is divided into eighteen watertight divisions, each compartment being provided with a separate pipe for pumping.

"The pumping machinery will be located in the port side wall with the main drain pipe at bottom of same and branches leading to the different compartments.

"The controlling valves will be operated from each engine room, and an operating house will be located on the top deck, with speaking tubes leading to the engine rooms, so that the operator in charge can at all times control the operation from the operating house, and, by means of indicators, fitted above each engine room, see how all the valves are being regulated.

"In the operating house will also be located an indicator system showing the depth of water in all the compartments.

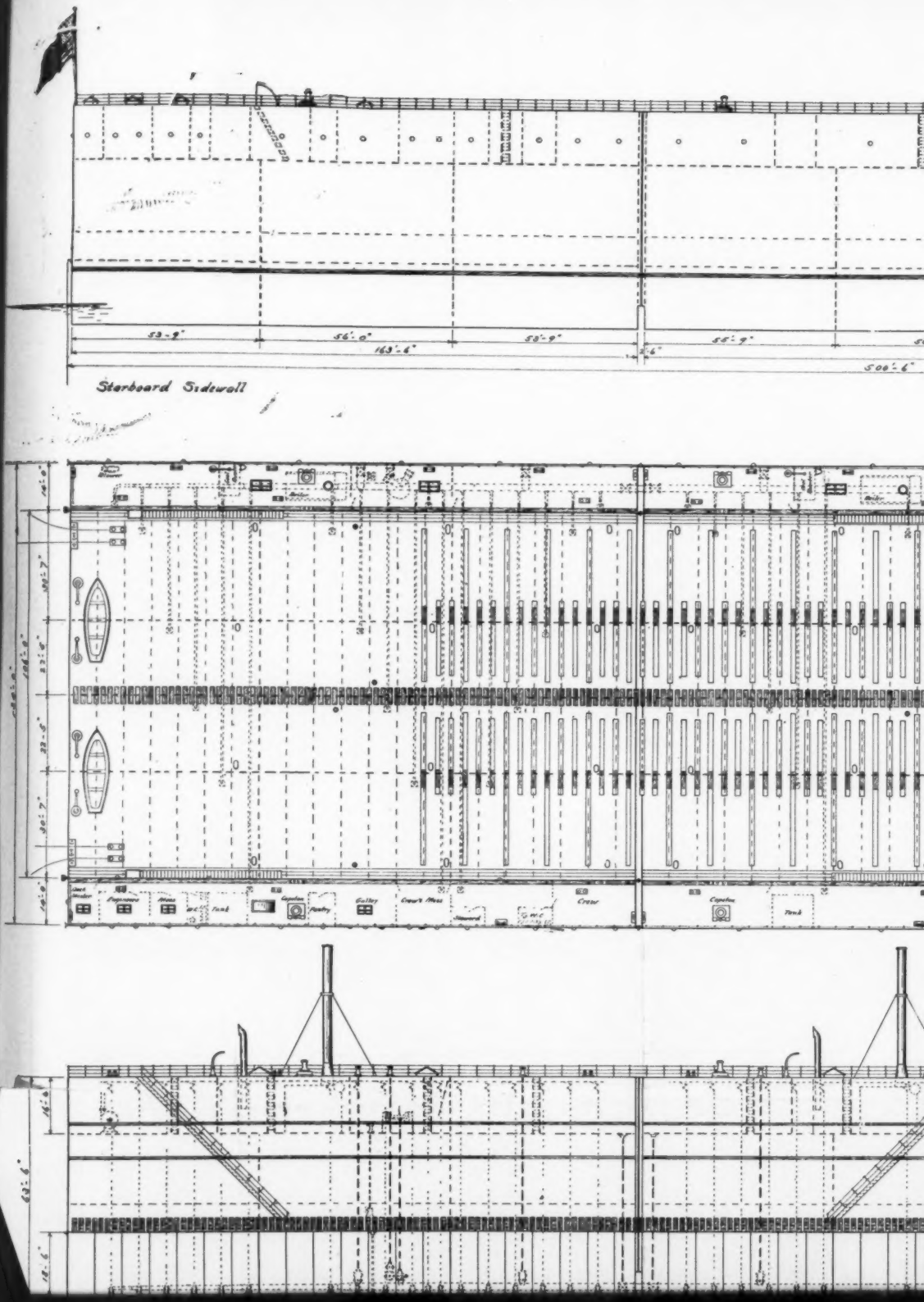
"The main pumping system to consist of three horizontal, direct-connected, compound engines, and steam will be furnished by three water-tube boilers. These pumps are sufficiently large to easily raise the structure within the time limit prescribed.

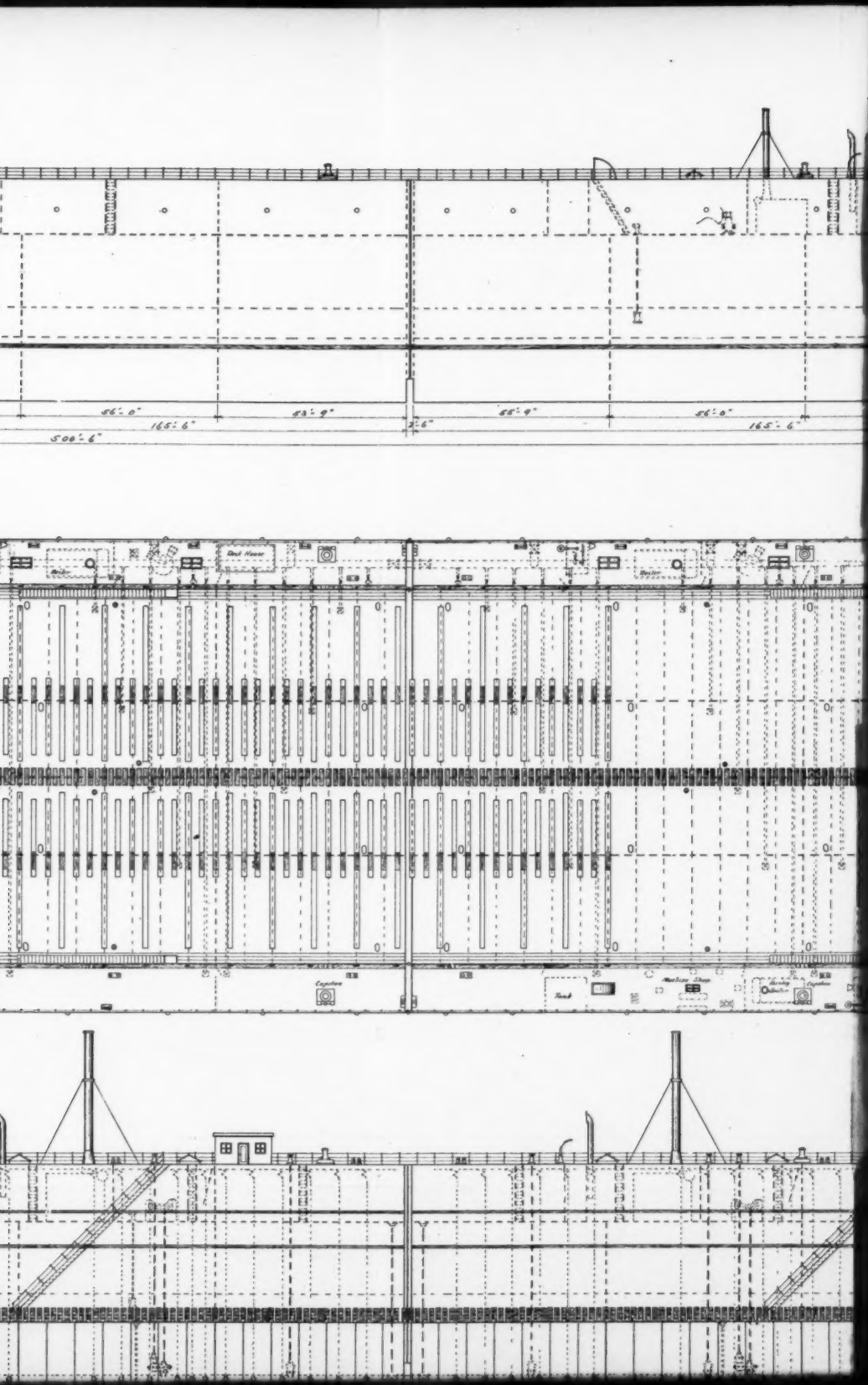
"An auxiliary boiler will provide steam for all the auxiliary machinery on the starboard side, such as capstans, electric plant, distilling plant and machine shop.

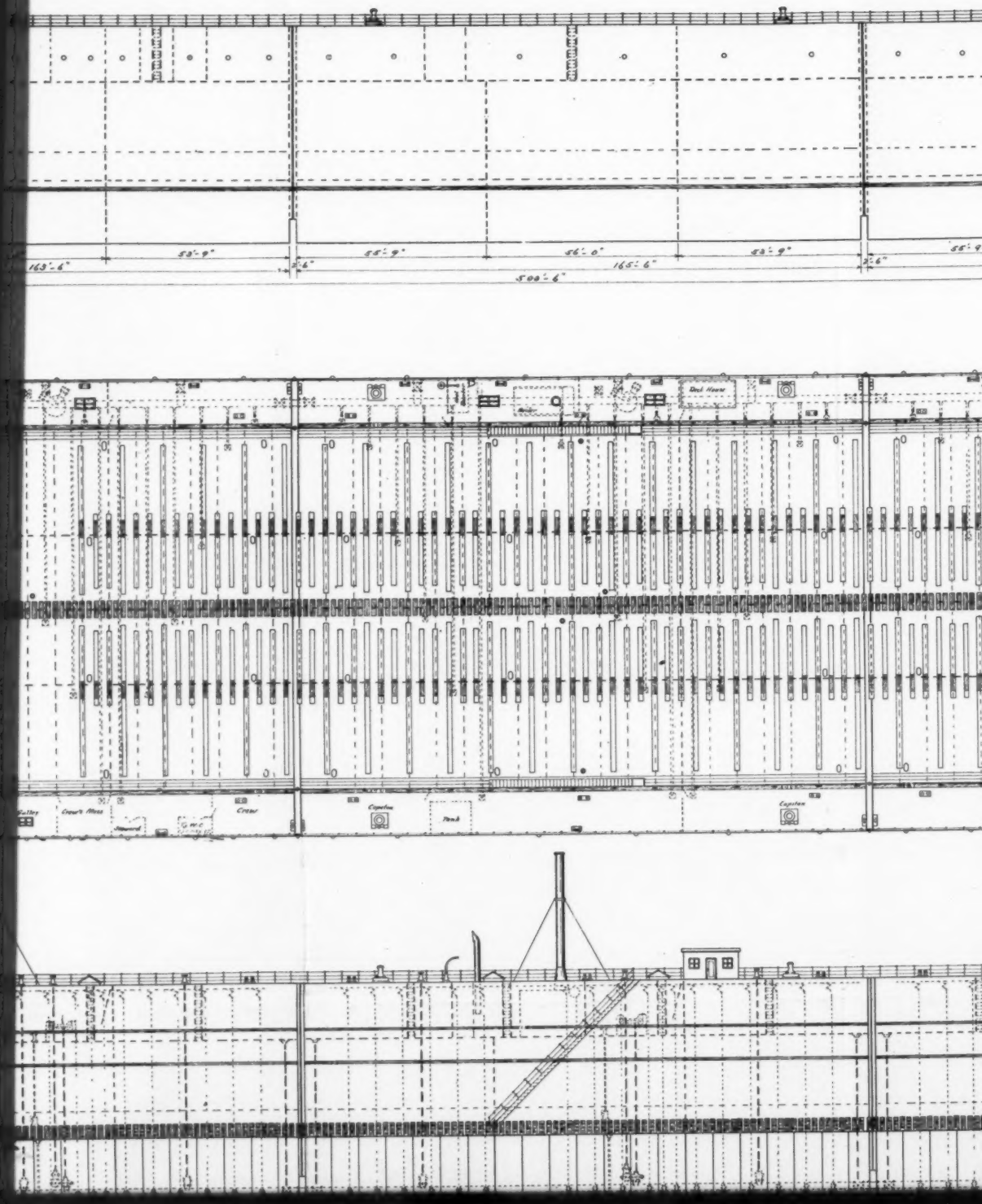
"On the side-wall decks will be located eight steam capstans and necessary bitts and fairleads for handling of lines when taking ships in and out of the dock.

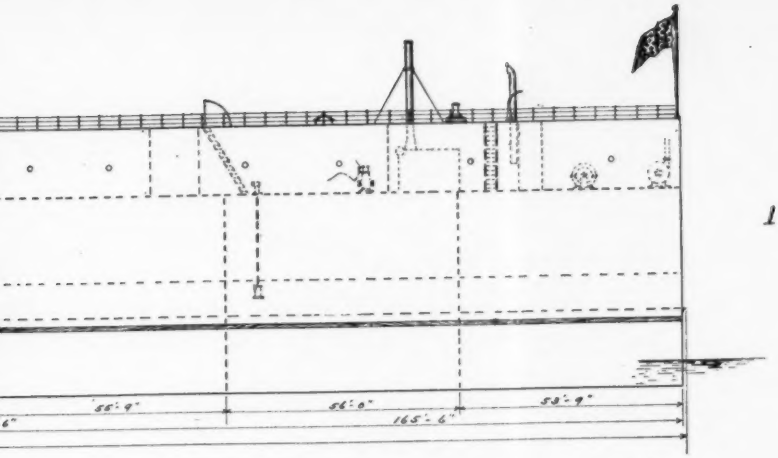
"A combined fire service and washing-down system is provided for protection of both ship and dock from fire, and the washing-down system will greatly facilitate the cleaning of ships when docked.

"The dock will be moored by two sets of heavy anchors, and chain cables at each corner fastened to heavy bitts, leaving the

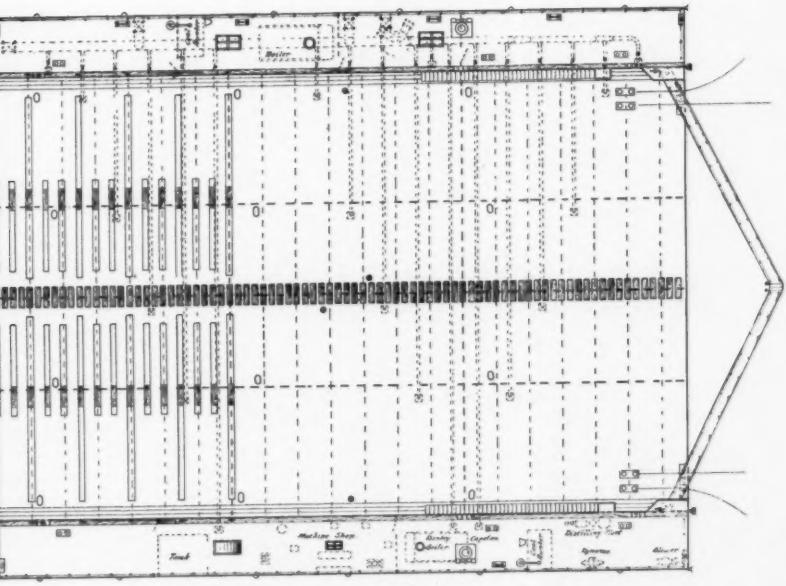

53'-2"
56'-0"
58'-9"
58'-9"
163'-4"
2'-6"
500'-6"
Starboard Sidewall


56'-0"
165'-6"
83'-9"
2'-6"
85'-9"
56'-0"
165'-6"
500'-6"
Deck House
Boiler
Boiler
Capstan
Capstan
Anchor Chain

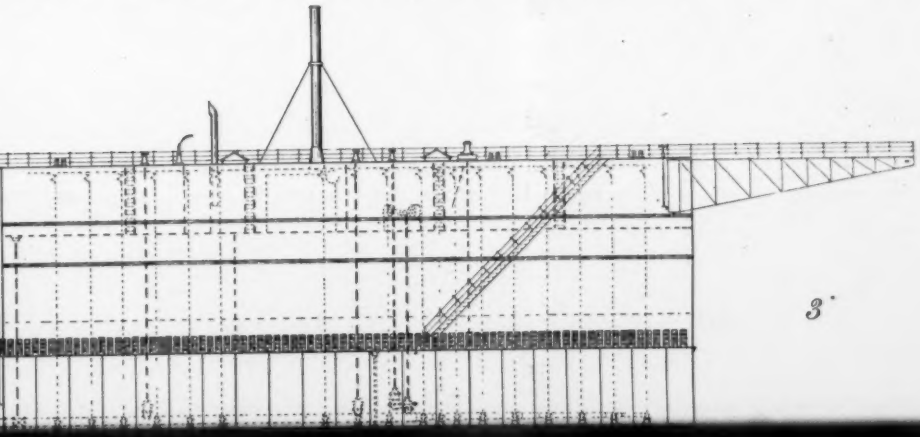

163'-6"
53'-9"
55'-9"
56'-0"
165'-6"
53'-9"
2'-6"
55'-9
500'-6"
Deck House
Capstan
Capstan



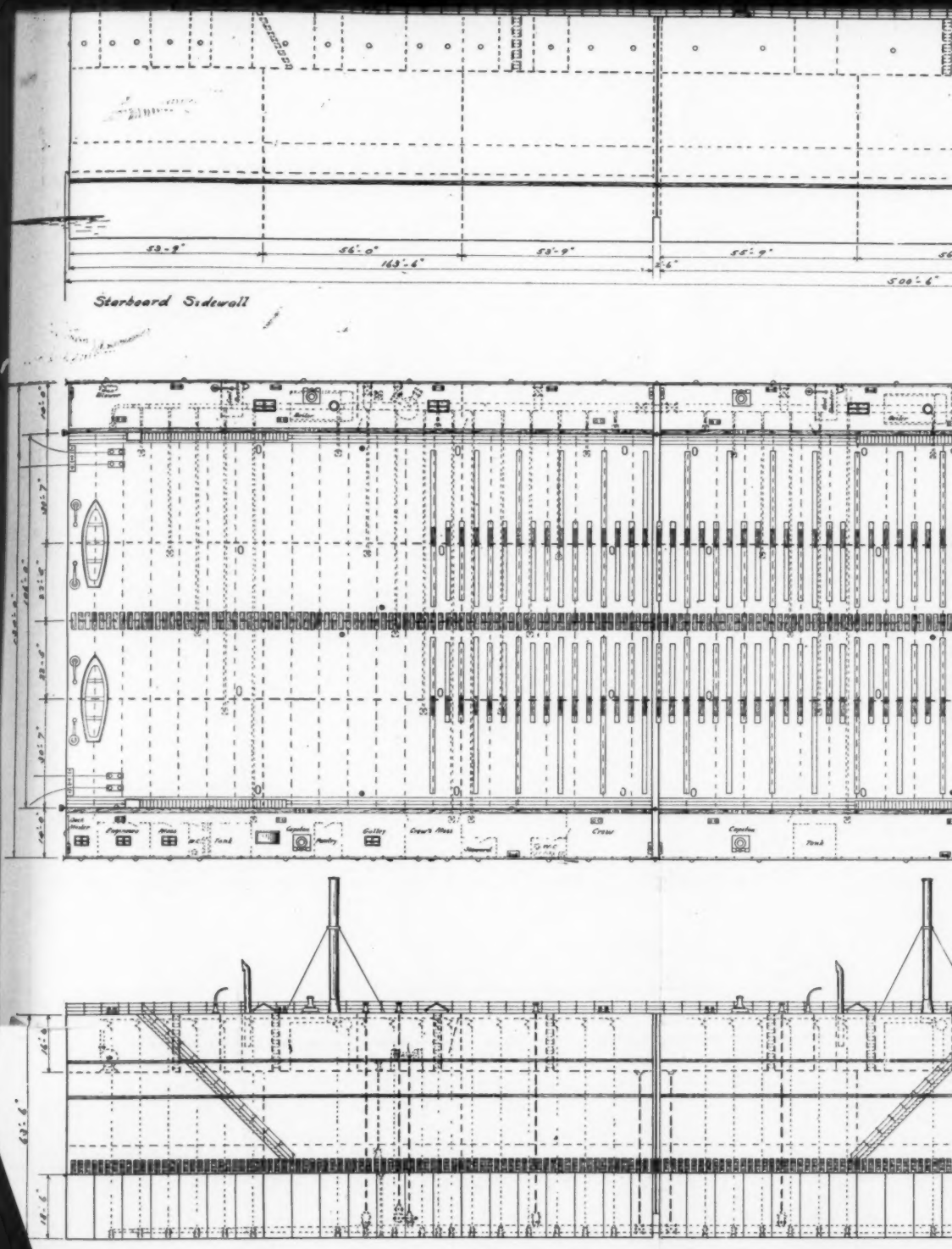

1



2



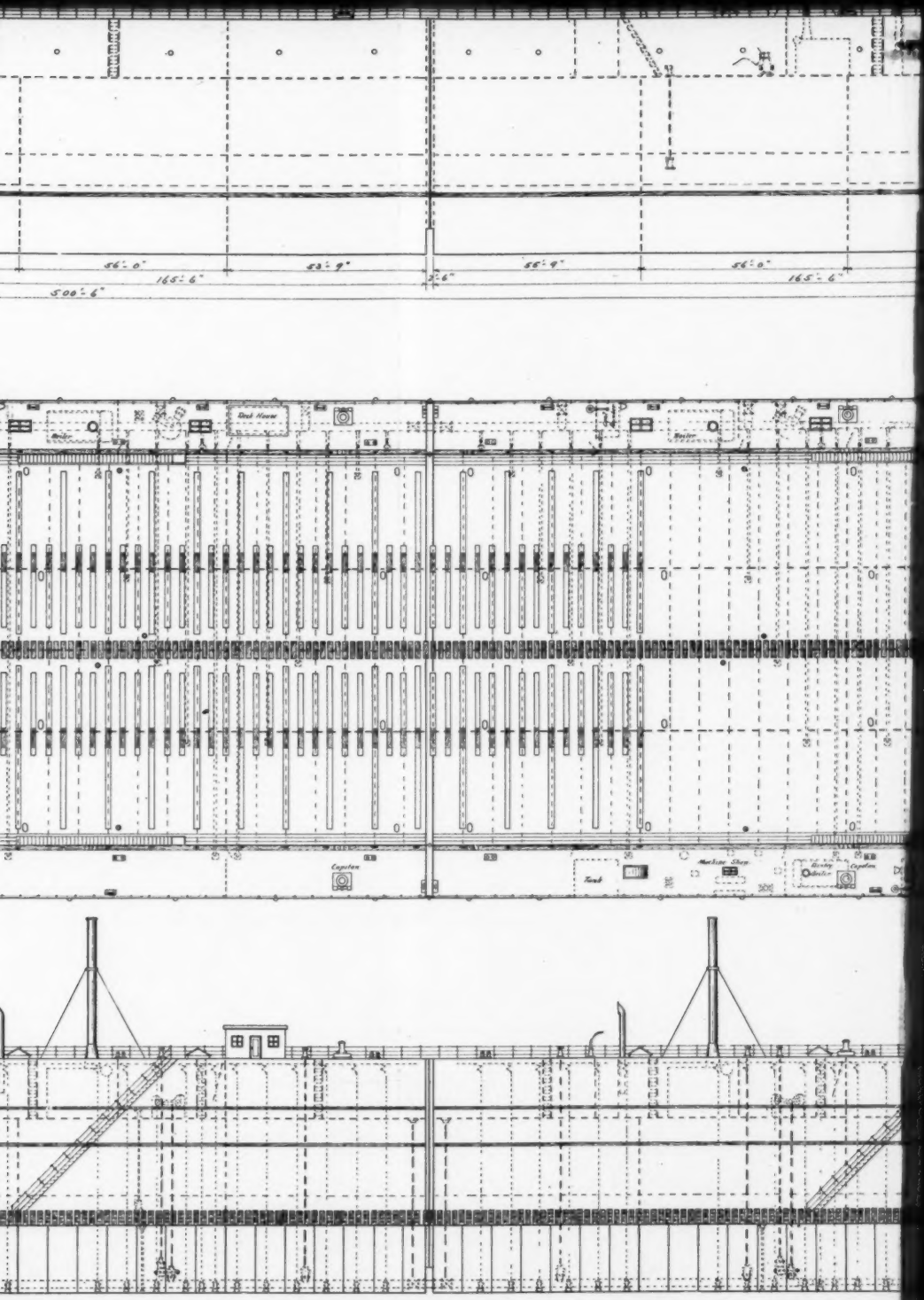
3




PROPOSED SELF-DOCKING STEEL FLOATING DRYDO

Maryland Steel Comp

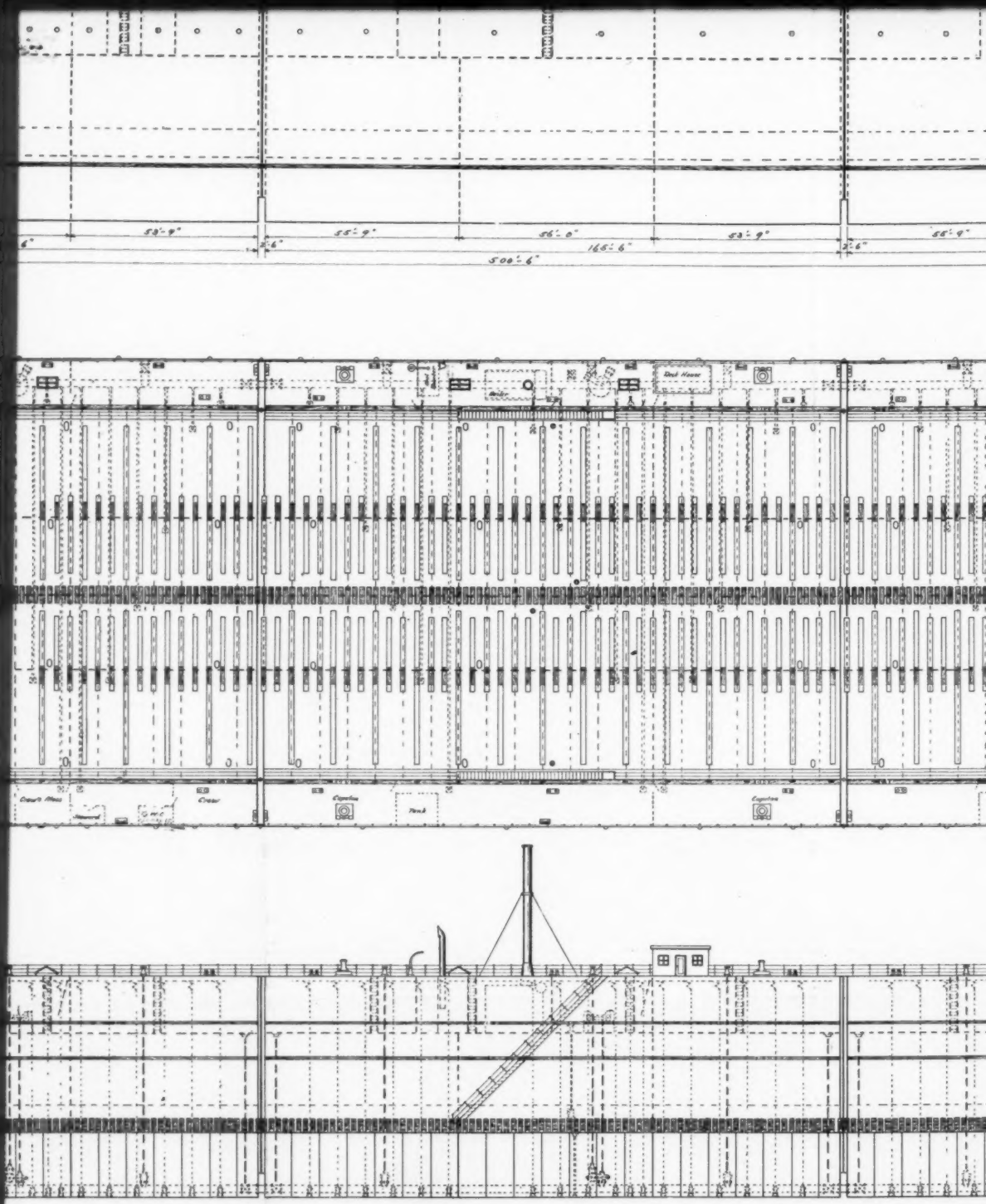
(1) Elevation of starboard side wall from outboard, showing junction of sections, lo
(2) Plan showing location of main pumping machinery in port side wall, arrangeme
(3) Sectional elevation of port side wall from inboard, showing location and distribu




TING DRYDOCK FOR U. S. NAVAL STATION, CAVITE, PHILIPPINE ISLANDS.

d Steel Company Design, Cunningham Type.

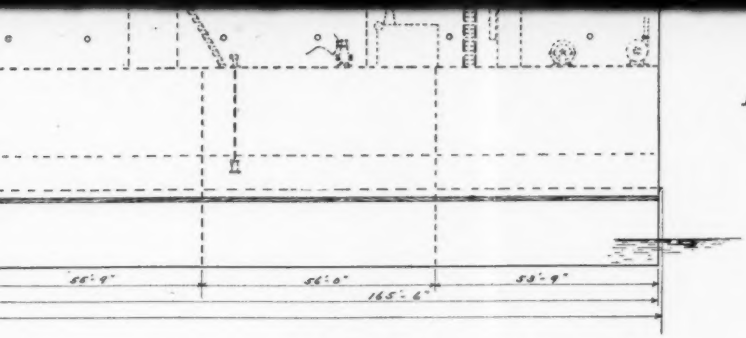
f sections, location of decks and bulkheads, and location of auxiliary machinery in bow and quarte
l, arrangement and distribution of piping, and location of girders and bulkheads in body of dock.
and distribution of machinery, pumps and valves.



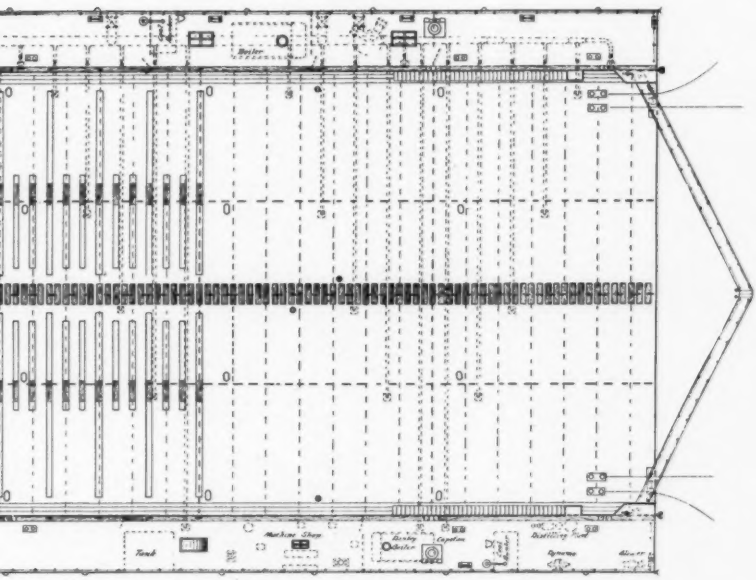

PROPOSED SELF-DOCKING STEEL FLOATING DRYDOCK FOR U. S. NAVAL STATION, CAVITE, PHILI

Maryland Steel Company Design, Cunningham Type.

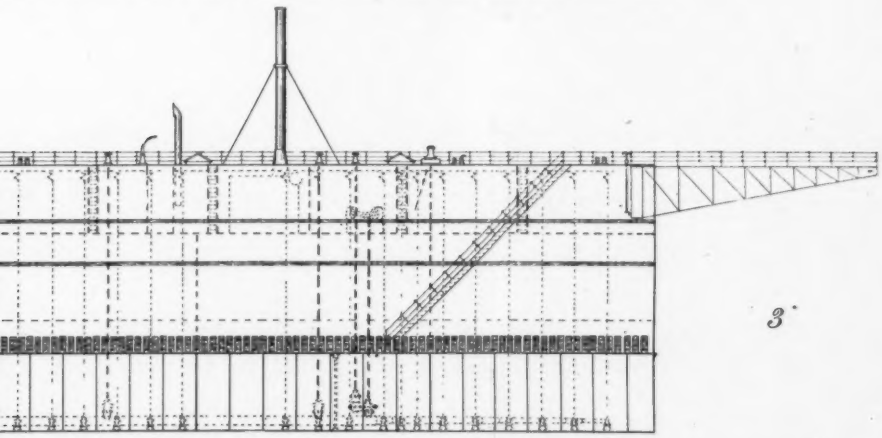
rboard side wall from outboard, showing junction of sections, location of decks and bulkheads, and location of aux
cation of main pumping machinery in port side wall, arrangement and distribution of piping, and location of girde
ion of port side wall from inboard, showing location and distribution of machinery, pumps and valves.




1




2



3

VITE, PHILIPPINE ISLANDS.

cation of auxiliary machinery in bow and quarters in stern.
tion of girders and bulkheads in body of dock.

dock free to sink and rise to the required depths in docking the vessel.

"The ship to be supported on three lines of blocking, the center line of keel blocks to be 2 feet centers, extending the whole length of the dock, and the side lines or docking keel blocks to be spaced 4 feet centers, and to extend fore and aft over a length, of 280 feet.

"The general features and all details entering into the design of this dock, both for the support of the ship, the operation of the dock, and the method of self-docking as described in the following specifications, are believed to fully meet the present and future needs of the naval service for safe docking all the present and to date projected ships of the United States Navy not over 16,000 tons displacement.

"The general arrangement of the dock is shown on Plan No. 1.

"Attention is particularly called to the fact that, with the bolted sectional type, the 500 foot-dock can at any time in the future be increased to about 666 feet in length by constructing a new intermediate section and adding it to the dock.

"This new section would be an exact duplicate of the present intermediate section, and during its construction the dock would continue in use to the time that the new section was ready to be installed in place. The installation of the new section would be accomplished in a few days, when the dock would be again ready for operation on an enlarged scale.

"With the increased length of the dock secured by the addition of a second intermediate section, it would no longer be desirable or necessary to employ uniform pumping for the loads for which the dock is at present designed. The actual lifting capacity of the dock would be increased to 24,500 tons, and when such load came upon the dock it would be so distributed as to give a correspondingly increased bearing, so that little or no pumping of the unloaded compartments would be required.

"With the limit of unit stress employed in the present dock and the small deflection permissible, the increased length resulting from the addition of a new intermediate section would still leave a dock in which no undue strains or deflection would occur

when handled with moderate intelligence and judgment by the dock master.

"This increase of length would bring a bolted section at the center of the dock where the greatest bending occurs, but additional intermediate flanges can be installed and bracketed back into the structure if it is desired to make this central joint unusually strong."

METHOD OF SELF-DOCKING.

"In self-docking the center section of the dock the water is first pumped down uniformly as low as practical in all the compartments with the drainage service. Water is then admitted freely to all compartments on the starboard side outboard of the starboard intermediate bulkhead, until the dock is heeled over sufficiently to bring the main drainage pipe on the port side well above water.

"The inner valves on the main drain pipe will be closed, and the drain pipe connections between the sections are then disconnected and removed. The water in the starboard compartments is now removed by the main pumps and the dock is emptied with the drainage pumps until light water line, about 6 feet, is reached and all the joint angles and bolts are above water. The drainage and fire mains are also to be disconnected on both sides. The connection bolts are then removed, except a few friction bolts in slotted holes on each side, which are loosened up gradually until each section reaches its own floatation, or, if found necessary, water is admitted until an equal balance is obtained. The remaining friction bolts are now taken out, leaving the pontoons floating independent of each other, held in position by hawsers.

"Thereafter, the water is admitted freely to all compartments in end pontoons Nos. 1 and 3 until a draught of 21 feet 5 inches is reached, and all three sections are brought together until slotted holes are fair with round holes and friction bolts are entered. Drift pins may now be inserted in round holes, and sections trimmed until all flanges bear and all holes are fair, after which all bolts are inserted and tightened up. The dock is now ready for lifting, and the water is pumped out of both end pon-

toons until the center pontoon has a draught of about 6 inches. At this stage the mud valves in the center pontoon are opened wide, permitting the remaining water to drain out of the center pontoon as the lifting progresses.

"In pumping the end pontoons the twelve compartments nearest to the center pontoon are pumped down to about 2 feet, and the six extreme end compartments in each end section are drained down to about 3 feet. The dock will then be found at a draught giving 5 feet in clear height between the water line and the bottom of the center pontoon. The bottom of the center pontoon can then be inspected, cleaned and painted or repaired from floats, all parts of the pontoon being easily accessible.

"In lowering the center pontoon all mud valves are closed and water is admitted freely to all compartments in the end pontoons until a draught is reached at which the center pontoon will float and all three sections are at a balance. All bolts in the joints are now removed except friction bolts in slotted holes, which are loosened gradually until each section slips to its own floatation. If a tendency of unequal balance is noted, water is admitted to overcome it, leaving the sections again floating independent of each other. The water in the end pontoons is now pumped out by the main pumps, and if necessary, by the drainage pumps until light water line is reached.

"If the stern pontoon, No. 3, has to be docked next, a hawser is passed from No. 1 to No. 3 on the outside of pontoon No. 2, which pontoon is now moved out sideways by means of a tug or kedge anchors and hawsers. When pontoon No. 2 is out of line a second hawser is passed between pontoons Nos. 1 and 3. The stern-anchor cables are now slipped, the ends being made fast to two buoys by suitable lines. No. 3 pontoon is now warped up close to pontoon No. 1, and No. 2 is placed in the position formerly occupied by No 3.

"The same method is now used in docking the stern pontoon, No. 3, between the other two pontoons, No. 1 and No. 2, as previously described in docking the center pontoon. After the stern pontoon, No. 3, is again afloat, the bow pontoon, No. 1, is handled in the same manner, and when the self-docking is finished

the pontoons are once more shifted into their original positions. All joints are bolted up and drainage and fire systems also connected. The dock is then heeled to starboard, the main drain-pipe connections on the port side again inserted, the water on the starboard side pumped out by the main pumps, and the dock is again floating in complete working order."

The method of self-docking is illustrated quite plainly in accompanying sketches.

### THE MARYLAND STEEL COMPANY TYPE.

This type was especially developed by the Maryland Steel Company to meet the conditions of the specification.

Of this design the builders state in their detail specification as follows:

### GENERAL DESCRIPTION.

"The proposed dock will be a self-docking, floating, steel structure, composed of side walls and pontoons with a general ⌊⌋ shaped cross section in three divisions, and so arranged that all three sections of the dock can be readily self-docked by means of the others without aid of auxiliary constructions.

"The dock will have a total length over all of 500 feet, a clear width between fenders on side walls of 100 feet, and a free-board of 11 feet with 30 feet of water above the keel blocks.

"The lifting capacity will be 16,000 gross tons or 32 tons per running foot over the entire length of the dock with the main deck 2 feet above water line and 1 foot of water remaining in all compartments.

"The dock is divided into three parts, one center pontoon, about 316 feet long, built solid into and between the two side walls which extend their full depth of 63 feet 6 inches over the entire length of the center pontoon, and at both ends are so arranged so as to overhang the end pontoons. The two end pontoons are each about 89 feet long and extend under the overhanging side walls, being strongly secured thereto by horizontal bolted connections.

"Both end pontoons are provided with outside independent side walls, extending the full length fore and aft of each end

ACCEPTED DESIGN SELF-DOCKING STEEL FLOATING DRYDOCK FOR U. S. NAVAL STATION, CAVITE, PHILIPPINE ISLANDS.
Maryland Steel Company Design and Type.
Plan showing self-docking of end and center sections.

pontoon, and of sufficient height to permit the end pontoons to be sunk and brought under the center pontoon when self-docking same.

"Each end pontoon can be manipulated in self-docking by a small independent pump and engine located on the port side in each pontoon, and by all the necessary valve gearing placed in the center of each pontoon side wall on the port side for this purpose.

"The end pontoons can be readily self-docked by lifting both at the same time on the deck of the center pontoon of the dock.

"The center pontoon is divided into twenty-four, and each end pontoon into eighteen, watertight compartments, making a total of sixty watertight divisions, each compartment being provided with a separate pipe for pumping.

"The main pumping machinery will be located in the port side wall, with the main drain pipe at the bottom of same and branches leading to the different compartments.

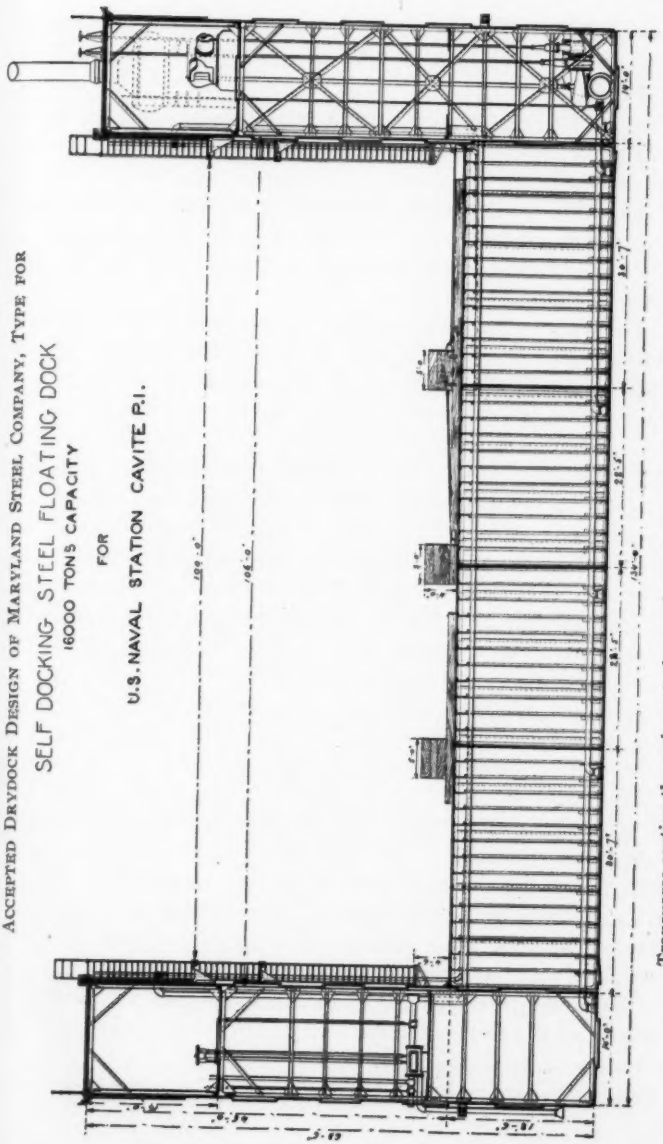
"The controlling valves will be operated from each engine room, and an operating house will be located on the top deck, with speaking tubes leading to the engine room, so that the operator in charge can at all times control the operation from the operating house, and, by means of indicators fitted above each engine room, see how all the valves are being regulated. In the operating house will also be located an indicator system showing the depth of water in all the different compartments.

"The main pumping system to consist of three 24-inch horizontal centrifugal pumps driven by three horizontal, direct-connected, compound engines, and steam will be furnished by three water-tube boilers.

"If preferred, a pumping plant of equal capacity, consisting of two 30-inch horizontal centrifugal pumps driven by two horizontal, direct-connected compound engines, may be installed, instead of the above three engines and pumps.

"An auxiliary boiler will provide steam for all auxiliary machinery on the starboard side, such as capstans, electric plant, distilling plant and machine shop.

"On the side-wall decks will be located eight steam capstans


ACCEPTED DRYDOCK DESIGN OF MARYLAND STEEL COMPANY, TYPE FOR
SELF DOCKING STEEL FLOATING DOCK
16000 TONS CAPACITY
FOR
U.S. NAVAL STATION CAVITE P.I.

Transverse section through central or main pontoon, showing location of machinery, pumps and piping.

and necessary bitts and fairleads for handling of lines when taking ships in and out of the dock.

"A fire and washing-down system is provided for the protection of both ship and dock from fire, and the washing-down service will be found to greatly facilitate the cleaning of ships when docked.

"The dock will be moored by two sets of heavy anchors and chain cables at each corner fastened to heavy bitts, leaving the dock free to sink and rise to the required depths in docking the vessel.

"The ship to be supported on three lines of blocking, the center line or keel blocks to be 2 feet centers, extending the whole length of the dock, and the side lines or docking keel blocks to be spaced 4 feet centers and to extend fore-and-aft over a length of 280 feet.

"The general features and all details entering into the design of this dock, both for the support of the ship, the operation of the dock and the method of self-docking as described in the following specifications, are believed to fully meet the present and future need of the naval service for safe docking all of the present and to date projected ships of the United States Navy not over 16,000 tons displacement.

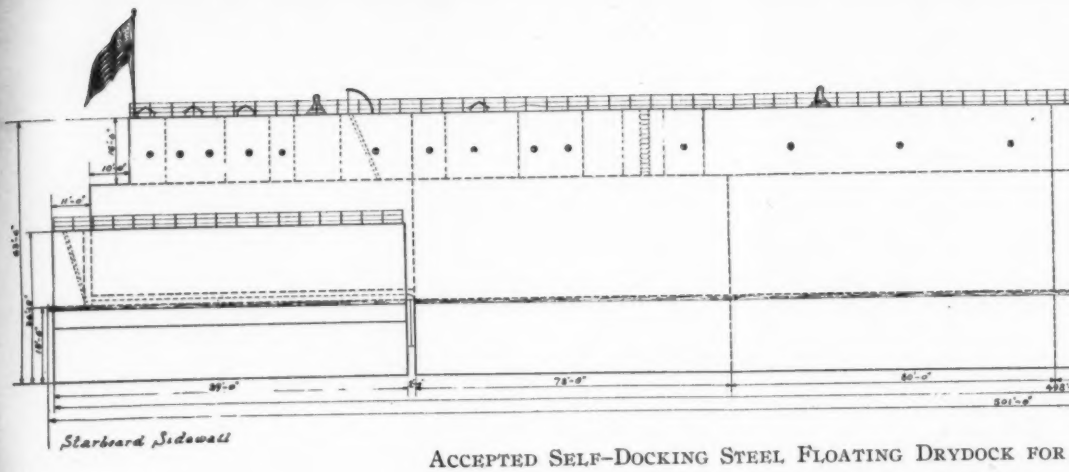
"The general arrangement of the dock is shown on plan No. 1.

"Attention is particularly called to the fact that this type of dock possesses simplicity combined with great rigidity, having a solid center portion of great length and as short end pontoons as practical.

"As the divisions of the pontoons come considerably outside of the turrets in the heaviest battleships or cruisers of the United States Navy, the bending moment at this point is reduced to nearly one-third of the maximum bending moment existing at the center of the dock when vessels of this class are docked.

"Furthermore, the side walls are built solid, full depth into the whole length of the center pontoon and continuous above the deck of the end pontoons, being entirely free from joints or connections above this point.

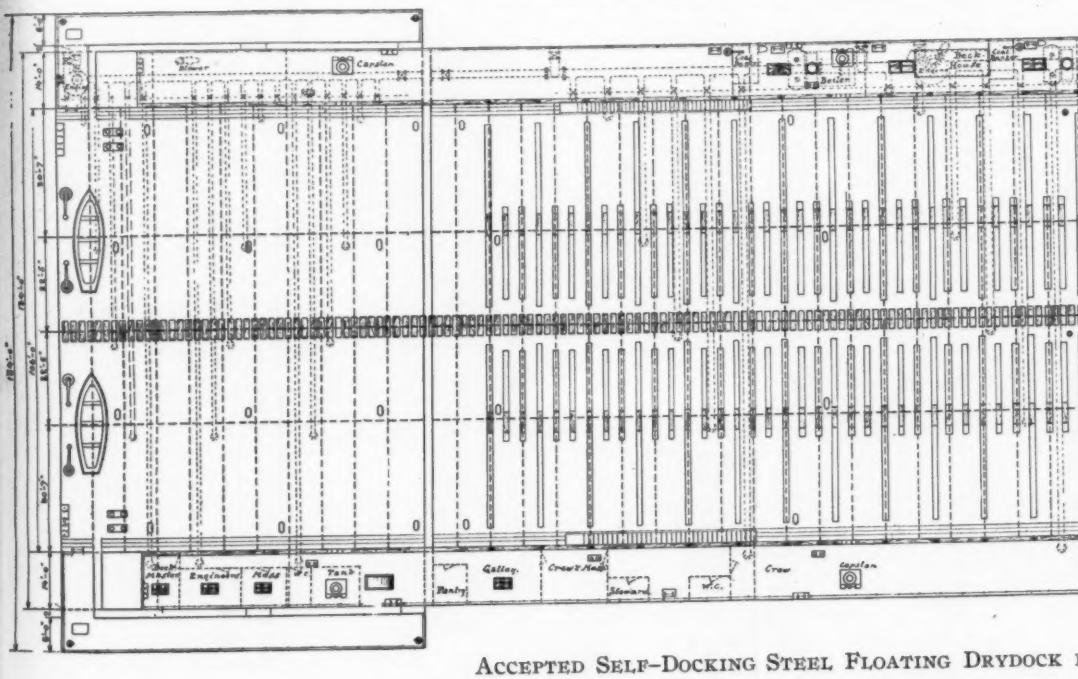
"Attention is further called to the simple method of self-




ACCEPTED SELF-DOCKING STEEL FLOATING DRYDOCK FOR

Maryland Steel Compan

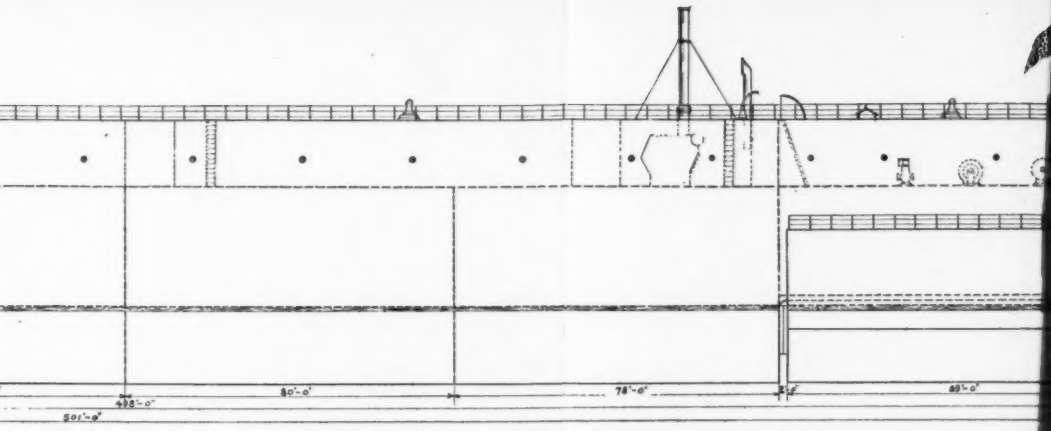
Elevation of starboard side wall from outboard, showing




ACCEPTED SELF-DOCKING STEEL FLOATING DRYDOCK

Maryland Steel Com

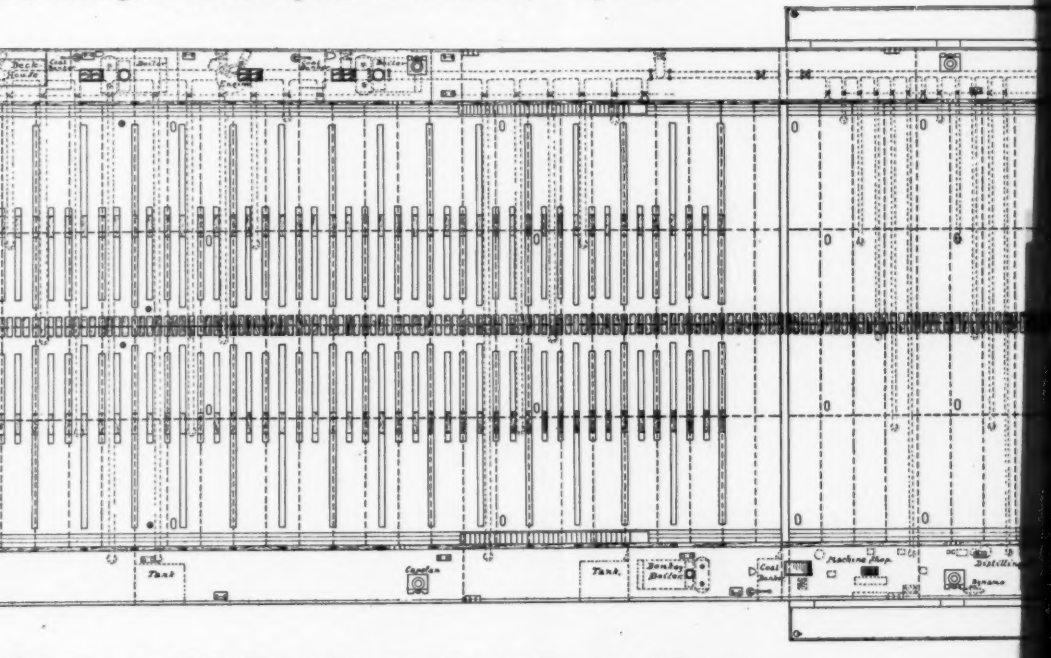
Plan showing location of pumping machinery in port side wall, distribution of water



RYDOCK FOR U. S. NAVAL STATION, CAVITE, PHILIPPINE ISLANDS.

Steel Company Design and Type.

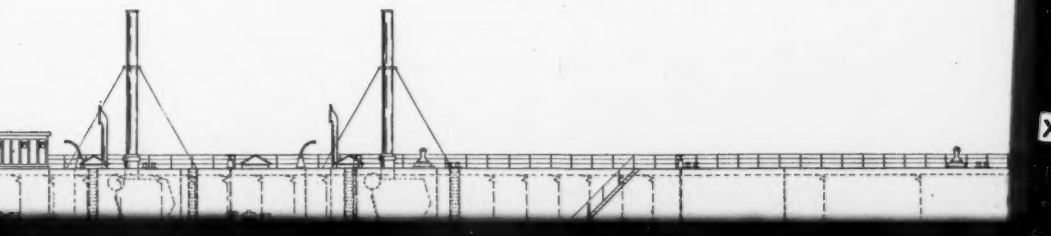
ard, showing end sections in position and dock ready for operation.

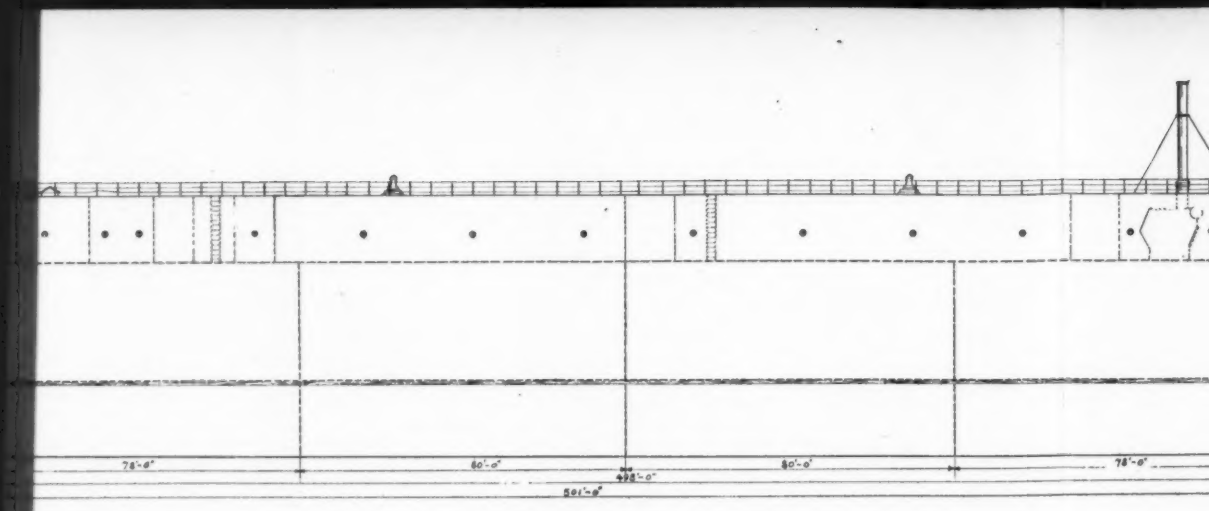


DRYDOCK FOR U. S. NAVAL STATION, CAVITE, PHILIPPINE ISLANDS.

nd Steel Company Design and Type.

ion of watertight bulkheads and piping, and end sections in position, with dock ready for operation

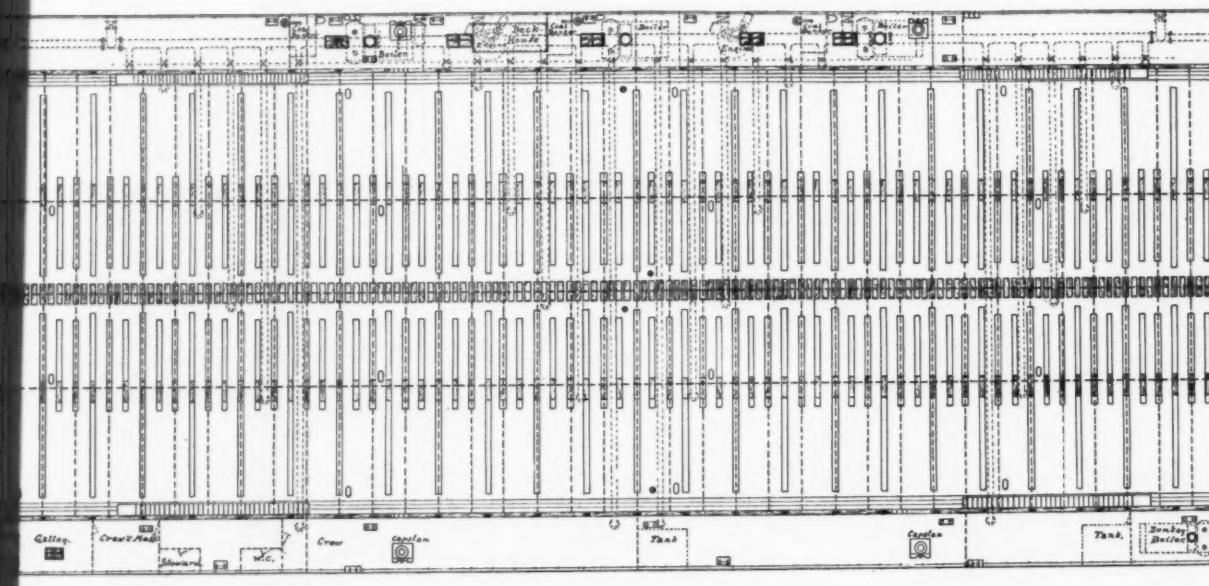





CEPTED SELF-DOCKING STEEL FLOATING DRYDOCK FOR U. S. NAVAL STATION, CAVITE, PHILIPPINE ISLAND

Maryland Steel Company Design and Type.

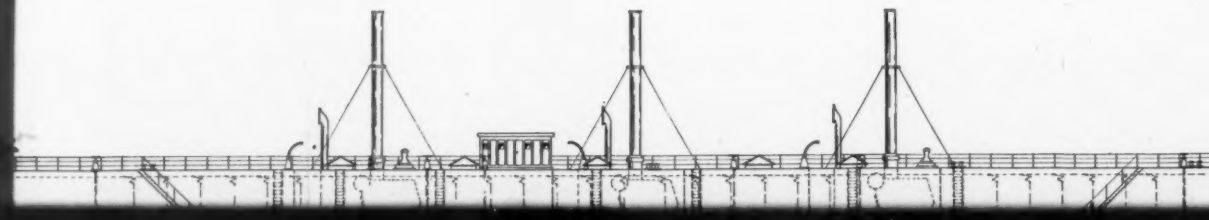
Elevation of starboard side wall from outboard, showing end sections in position and dock ready for operation.

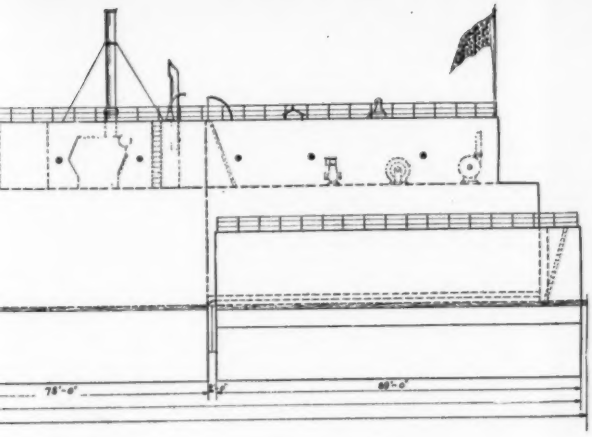



ACCEPTED SELF-DOCKING STEEL FLOATING DRYDOCK FOR U. S. NAVAL STATION, CAVITE, PHILIPPINE ISL

Maryland Steel Company Design and Type.

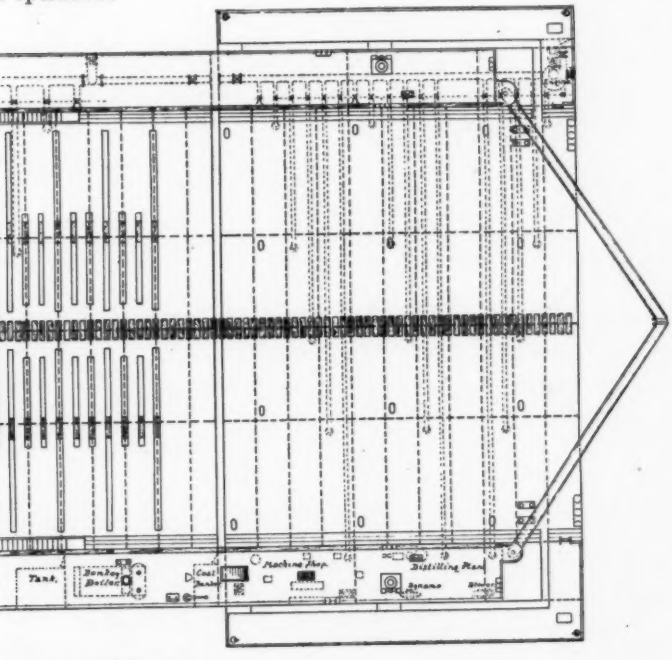
pumping machinery in port side wall, distribution of watertight bulkheads and piping, and end sections in position,





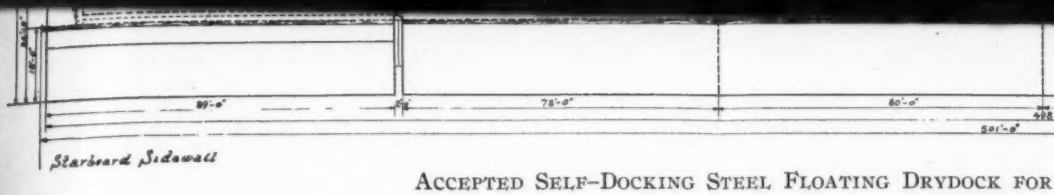
PPINE ISLANDS.

r operation.




HILIPPINE ISLANDS.

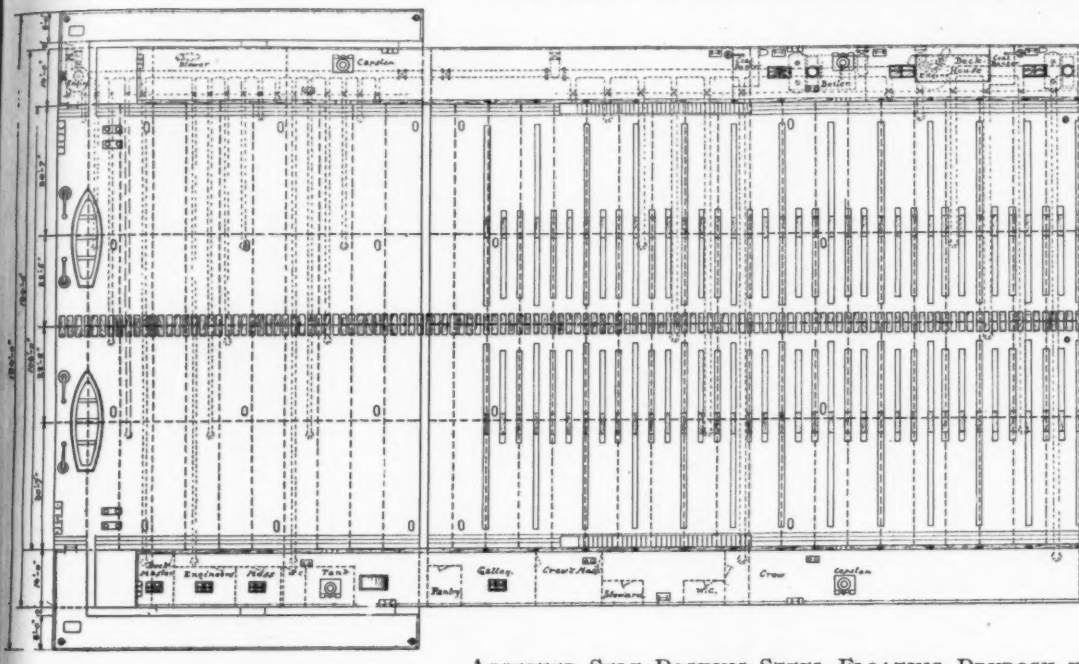
ns in position, with dock ready for operation.




ACCEPTED SELF-DOCKING STEEL FLOATING DRYDOCK FOR

Maryland Steel Compan

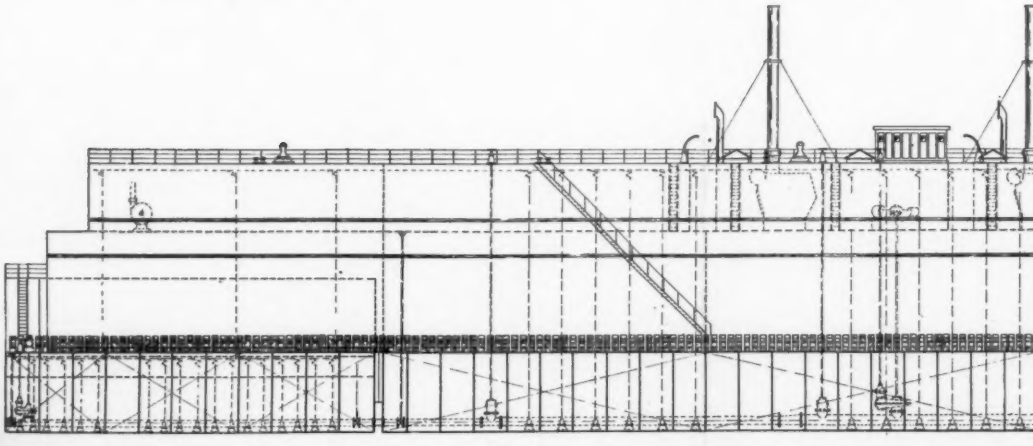
Elevation of starboard side wall from outboard, showing




ACCEPTED SELF-DOCKING STEEL FLOATING DRYDOCK F

Maryland Steel Comp

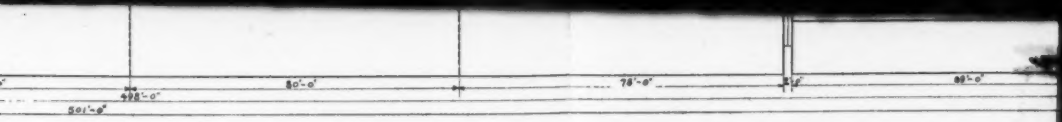
Plan showing location of pumping machinery in port side wall, distribution of waterti




ACCEPTED SELF-DOCKING STEEL FLOATING DR

Maryland

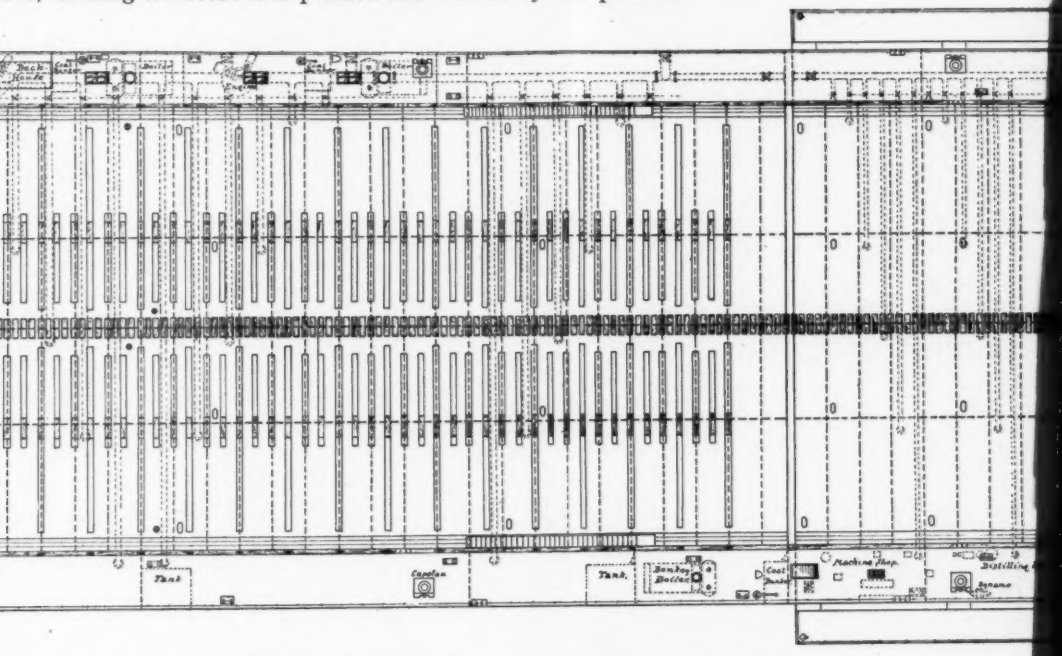
Sectional elevation through port side wall, showing location of p



ORYDOCK FOR U. S. NAVAL STATION, CAVITE, PHILIPPINE ISLANDS.

Steel Company Design and Type.

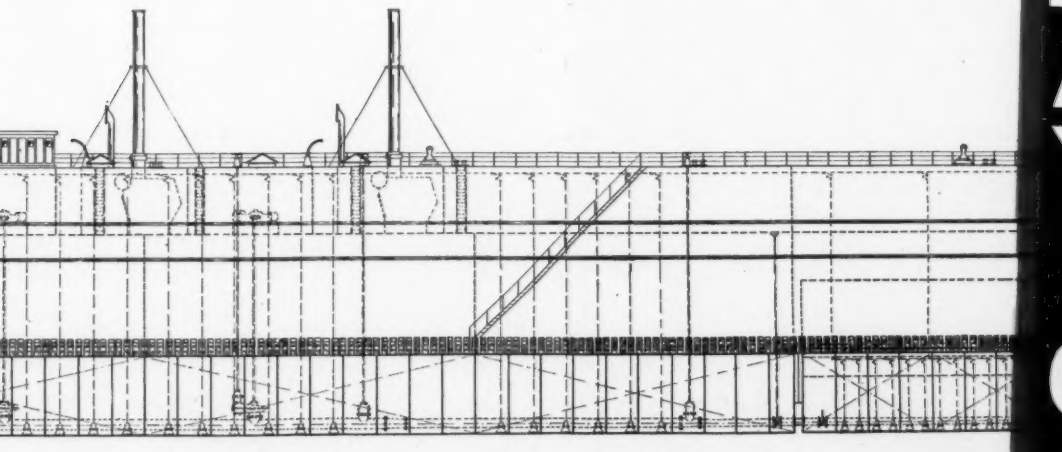
ard, showing end sections in position and dock ready for operation.



G DRYDOCK FOR U. S. NAVAL STATION, CAVITE, PHILIPPINE ISLANDS.

nd Steel Company Design and Type.

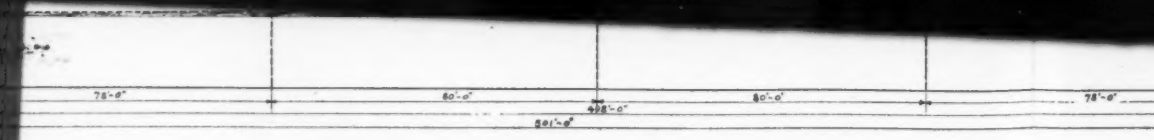
tion of watertight bulkheads and piping, and end sections in position, with dock ready for operation



LOATING DRYDOCK FOR U. S. NAVAL STATION, CAVITE, PHILIPPINE ISLANDS.

Maryland Steel Company Design and Type.

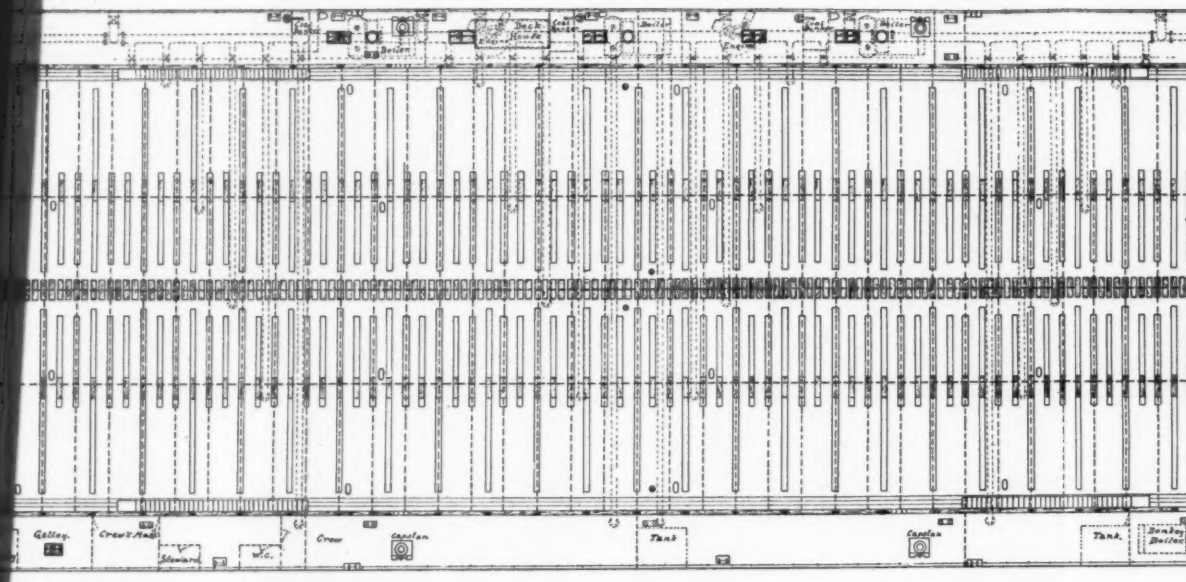
location of pumping machinery and distribution of valves and pumps in center and end sections.



EPTED SELF-DOCKING STEEL FLOATING DRYDOCK FOR U. S. NAVAL STATION, CAVITE, PHILIPPINE ISLA

Maryland Steel Company Design and Type.

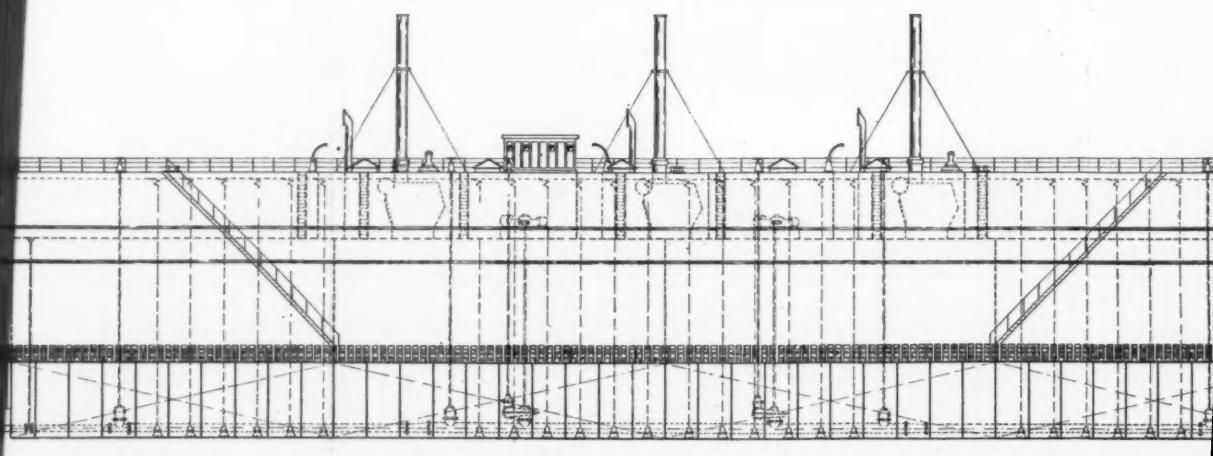
Elevation of starboard side wall from outboard, showing end sections in position and dock ready for operation.



ACCEPTED SELF-DOCKING STEEL FLOATING DRYDOCK FOR U. S. NAVAL STATION, CAVITE, PHILIPPINE I

Maryland Steel Company Design and Type.

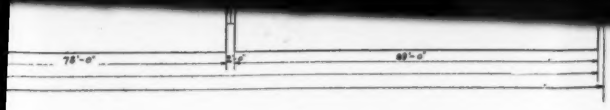
f pumping machinery in port side wall, distribution of watertight bulkheads and piping, and end sections in positio



ACCEPTED SELF-DOCKING STEEL FLOATING DRYDOCK FOR U. S. NAVAL STATION, CAVITE, PHIL

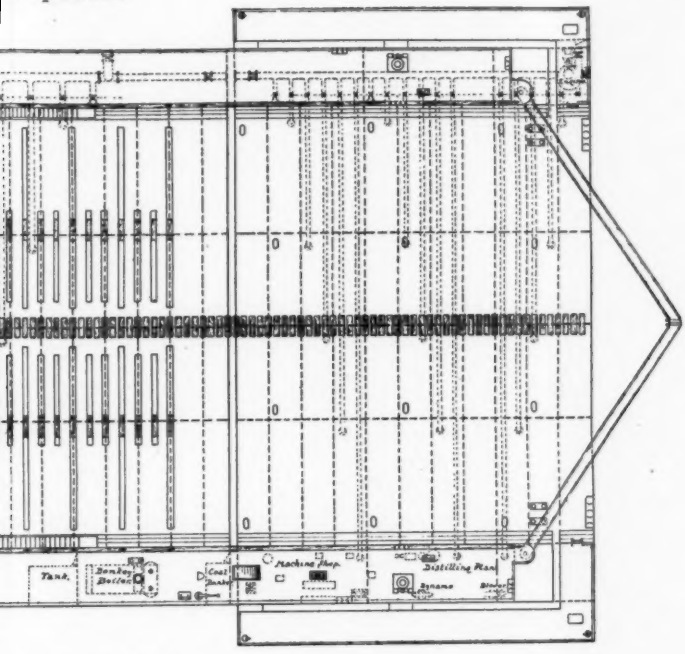
Maryland Steel Company Design and Type.

Sectional elevation through port side wall, showing location of pumping machinery and distribution of valves and pun



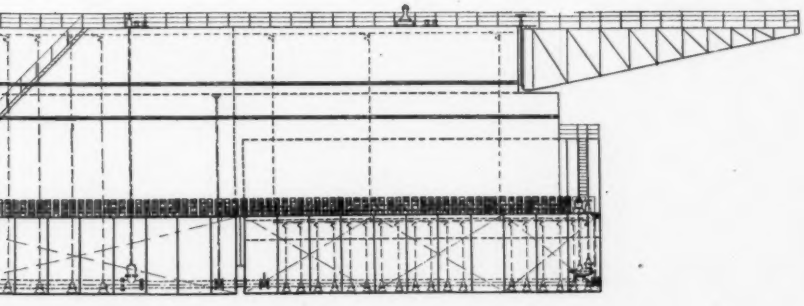
IPPINE ISLANDS.

or operation.




PHILIPPINE ISLANDS.

ons in position, with dock ready for operation.



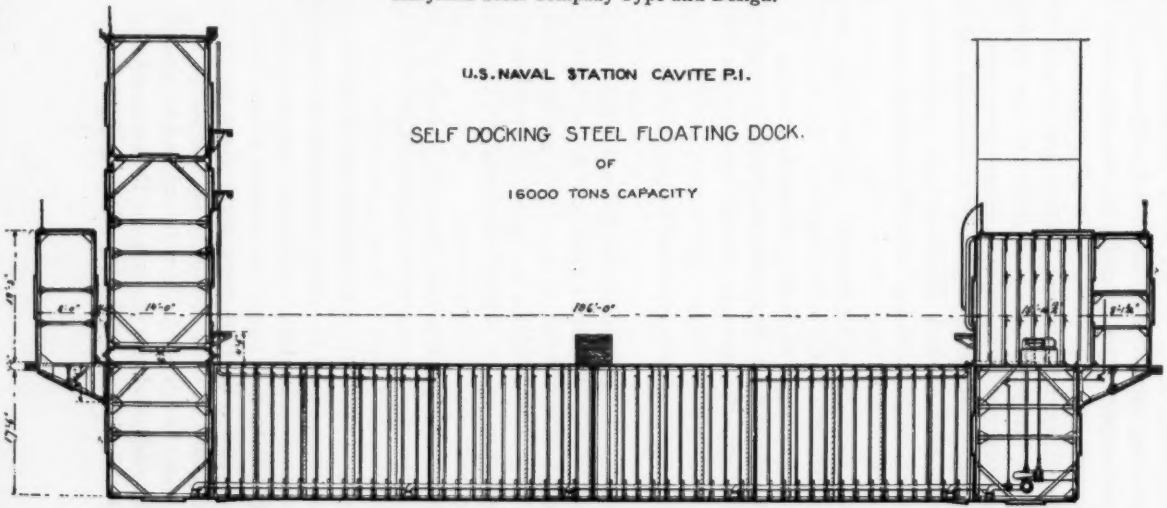
AVITE, PHILIPPINE ISLANDS.

lves and pumps in center and end sections.

ACCEPTED DESIGN FOR SELF-DOCKING STEEL FLOATING DRYDOCK.

ACCEPTED DESIGN FOR SELF-DOCKING STEEL FLOATING DRYDOCK.

Maryland Steel Company Type and Design.




Cross section through end pontoon, showing supplementary side walls, chamber at end for location of operating machinery, and connection at left between main side wall and end section.

docking the whole dock, comparatively few bolts in the connections requiring removal only once, and all three sections can be lifted and supported on blocking in the same manner as a vessel is docked.

"In self-docking, no joints or bolted connections whatever are subject to heavy strains or are required for docking the different sections, and as no delicate adjustments of water levels for careful manipulations for balancing the different sections are required, this type of dock can be quickly self-docked when handled with moderate intelligence and judgment by the dock master.

"The side walls being continuous, communication is easily established throughout the entire length of the side walls, and simplicity and convenience being desirable features, the main boilers and engines have been concentrated in the center of the port side wall with the operating house directly above the pumping plant.

METHOD OF SELF-DOCKING.

"When self-docking the dock, the water is first pumped out as low as practical with the main pumps, and water is then freely admitted to all compartments on the starbord side outside of the starboard immediate bulkhead in the center pontoon only until the dock is heeled over sufficiently to bring the main drainage pipe on the port side well above water.

"The inner valves on the main drain will be closed, and the drain pipe connections between the pontoons are then disconnected and removed.

"The water in the starboard compartments of the center pontoon will be removed by the main pumps and the dock lifted to light water line. All anchor cables are now slipped, the ends being made fast to four buoys by suitable lines. For holding the dock in position lines are made fast to these buoys and lead up to the capstans on deck at ends of side walls.

"Every other keel block to be removed, and the docking keel blocks will be adjusted so as to support the end pontoons under the transverse bulkheads. The top blocks will be capped with

ordinary pine plank 3 inches by 12 inches spiked thereto for protection of the oak blocking.

"The bolts in all connections between pontoons will now be removed and sufficient water admitted to the end pontoons until a fair clearance is obtained between the connection angles. The end pontoons will then be warped out by the capstans and hawsers and turned around ready to enter the center pontoon between the side walls. The center pontoon is now sunk down to a depth sufficient to give about 1 foot clearance between the top of blocking and bottom of end pontoon, and the pontoons are warped in over the center pontoon and held centrally so that the docking keel blocking will come directly under the transverse bulkheads.

"The center pontoon is now pumped up by the main pumps equally from all compartments until the deck is 1 foot or more above the water line. The bottom and the lower sides of the end pontoons can now be inspected, cleaned, painted or repaired, all parts being easily accessible, with ample working spaces all around the pontoons.

"While inspection of the bottom of the end pontoons is going on the blocking on the deck of the end pontoons shall be adjusted so as to carry the center pontoon directly under all longitudinal bulkheads. Every other keel block will be removed, and all top blocks will be capped by 3-inch by 12-inch pine planking.

"The center pontoon will now be lowered by admitting water freely to all compartments until end pontoons are floating free, when they are warped out by the capstans between the side walls and held clear of the center pontoon, which is then pumped up to light-draught water line by the main pumps.

"The end pontoons are now floated out, turned around and sunk down sufficiently to be warped under the center-pontoon side walls, water being admitted through the flushing valves in the end compartments.

"The end pontoons will be held by hawsers in their original positions while water is again admitted, and the pontoons are lowered until the deck is about one foot above the water line.

"The steam connection between the auxiliary steam pipes and the side walls is now made, the steam swinging joints giving perfect freedom for the pontoon to be moved as required.

"The end pontoons are now sunk until a clearance of about one foot between the blocking and the bottom of the center pontoon is obtained, and gradually warped under same.

"As soon as both end pontoons are in proper position pumping is commenced by the 12-inch pumps in the end compartments and continued equally from all end pontoon compartments until the bottom of the center pontoon is 5 inches above water line.

"The bottom of the center pontoon is now accessible for inspection or repair, and all parts of the whole dock have been self-docked.

"Inspection completed, the center pontoon will be lowered by admitting water freely to all compartments in both end pontoons until afloat, when the end pontoons are moved to their original position and pumped up ready for connection to the center pontoon.

"All connection bolts are now inserted and the dock heeled to starboard, the main drain-pipe connections on the port side again inserted, the water on the starboard side pumped out by the main pumps, and the dock is again floating in complete working order."

The method of self-docking is a development of existing designs.

It will be noted that power is conveyed to the small end docks by a flexible connection.

In this type of dock the width and length are functions of each other. The small end docks must have sufficient displacement to lift the main section. As the main section increases in length the end sections necessarily increase in length in order to have the displacement to lift it, and the main section must therefore be made wide enough to take the end sections on its deck.

### THE CUNNINGHAM TYPE IN 450 FEET LENGTH.

This proposal is for a dock in all respects similar to the dock already illustrated, except in length.

Of this proposal the bidders state as follows:

POSSIBILITIES OF THE BOLTED SECTIONAL DESIGN.

"Especial attention is called to the bolted sectional dock of 450 feet in length in connection with the possibilities of future lengthening of the structure. From the recent and latest developments in battleships, it seems a fair assumption that the 450-foot dock will supply all the bearing length and lifting power that will be needed for battleships for many years to come. It will more than supply the lifting power for armored cruisers, whose length seems to have reached a standstill for the present. As the 450-feet dock has more bearing length than is needed for the armored cruisers, it seems unnecessary waste of material to make a dock 500 feet long simply for the purpose of providing a working platform when the same can be much more economically obtained by the use of independent floating pontoons.

"It is true that with all types of floating drydocks, except the bolted sectional type, it is wise to provide for future unexpected expansion in ships, as the other types of docks are either entirely unadaptable to expansion or can only be expanded at much cost and serious loss of time, and when expanded become comparatively weak and flexible structures.

"Admitting, however, the possible desirability of expanding the 450-foot dock of about 17,000 tons lifting capacity to meet future conditions, the expansion is made to even greater advantage than in the case of a 500-foot bolted sectional type.

"The expansion is made by the addition to the structure of an intermediate section which is a duplicate of the others. The dock then reaches the length of about 600 feet and a lifting capacity of about 22,800 tons, which seems to be a requirement in excess of the developments in warships that are estimated on by the most radical minds.

"The indicated development of this 450-foot dock also produces a structure in which the original conditions of unit stress, uniform pumping and deflection under loading are more closely preserved to the usual floating dock practice.

"The dock desired by the Government in the Philippine Islands

is of a type suitable for the heaviest ships. Such a dock will necessarily dock all the smaller ships down to gunboats and torpedo craft. As, however, the Philippine Archipelego demands a fleet of the smaller type of gunboats for its most successful policing and protection, the largest size of floating dock, in ordinary types, would generally be operated at a great disadvantage in docking such craft. With the bolted sectional type, however, as here presented, each section is a complete and perfect floating dock in itself, and can be so used. The advantages of a separate and independent use of each section for the rapid and economical docking of a large number of small craft are obvious.

"While it has no bearing on the present case, it seems desirable to call attention at this time to other possibilities of the bolted sectional type of dock.

"The cross section in the dock has dimensions and lifting-power per foot of length which are more than ample for any development that will take place in warships for many years to come, and can therefore be regarded as a safe standard. Should the Government in the future provide itself with several floating docks of the bolted sectional type and of a standard cross section, the combinations of the sections of the various docks that could be made for emergencies and unexpected conditions are very numerous. Take, for example, two standard docks of three sections each. By simply combining these sections we have at once a long four-section dock and a short two-section dock, or three short two-section docks.

"The various useful combinations that can be made with three or four standard docks, especially where the intermediate sections are of high strength, are readily apparent and too numerous to mention here in detail."

An advantage of this type of dock is that the sections can be built and launched separately, and each section towed independently if desired.

### THE POLA TYPE.

In order that this paper may be a complete review of military floating docks to date, plates of a general plan and the method of self-docking of the Pola dock are presented herewith.

This dock is being built by the Austrian Government for the Naval Station at Pola, and was designed by Mr. Lyonel Clark, of London, who designed the Clark dock previously mentioned, on which the Maryland Steel Company made a bid for the Cavite Naval Station.

It will be noted that it is a bolted sectional design. The bolts are carried around through a special chamber and below the water line of the dock, and it is believed that it will be difficult to keep them dry, and inconvenient to make and unmake the connection in self-docking operations on account of the flooding of the chamber.

This type of dock can only be self-docked in smooth water, where there is little current.

### SUCCESS OF MILITARY FLOATING DOCKS.

The success of the New Orleans military dock has carried this class of structure past the experimental stage. Its suitability for docking a first-class battleship was doubted by many experts, both naval and civilian, and its construction, voyage and test were matters of deep interest to the naval authorities of all maritime nations.

The comprehensive and exacting requirements of the new specification placed the success of the Cavite military dock beyond question, and marks a new era in this class of naval architecture.

Should the Government decide to tow this dock to its destination with its own naval resources, a new and vastly important maneuver will also have been added to naval practice.

# THE MILITARY IMPORTANCE OF NAVAL ENGINEERING EXPERIMENTS.

## THE SCOPE AND PURPOSE OF THE NAVAL ENGINEERING LABORATORY TO BE ESTABLISHED AT THE NAVAL ACADEMY.

By Rear Admiral George W. Melville,
Engineer-in-Chief, U. S. N.

[Address delivered before The Engineers' Club of Philadelphia, May 2, 1903.]

---

The Act making appropriations for the naval service for the fiscal year commencing July 1st, 1903, contained a larger appropriation for new construction than any Act heretofore passed by a Congress of the United States. This Act not only provided for the construction of three first-class battleships of not more than 16,000 tons, and two first-class battleships of not more than 13,000 tons displacement, but it likewise authorized the building of a naval engineering laboratory whose cost, including equipment, should not exceed $400,000.

### COST AND DEPRECIATION OF MODERN BATTLESHIPS.

The hulls and machinery of these five battleships will cost approximately $20,000,000. The armor, armament and equipment will require an additional outlay of $15,000,000; so that the actual cost of these battleships will probably be about $7,000,000 each. The annual depreciation of each of these vessels from the time they are launched, taking into consideration wear and tear as well as loss in fighting value, will be at least 4 per cent. of their actual cost. The expense attending the establishment of the proposed experimental station, including its operation for several years, will thus be but little more than the annual loss resulting from corrosion, mishaps and depreciation of military appliances of two of these floating fighting machines.

THE EXCELLENCE OF GERMAN NAVAL AND MARITIME CONSTRUCTION.

The rise of Germany as a naval and maritime power during the past thirty years has surprised the world. I believe that her battleships for their tonnage are the best afloat, because they possess a triple-screw installation of machinery, thus giving the motive power of her larger warships economical, structural and tactical advantages over similar high-powered vessels of rival nations. Her ocean greyhounds are the largest, fleetest and probably the most economical and comfortable afloat. Strangest of all, this excellence in the construction of warships, as well as in the building of vessels for the ocean-going trade, is not the result of a progressive series of failures, either in design, construction or of operation.

The success of Germany can only be accounted for by recognizing the fact that study, reflection and research must have been expended in the preparation of plans, in the building up and the organization of the shipyards, and in laying out and carrying on the work of construction. It was the high appreciation of the value of original investigation, coupled with experimental work, that has caused Germany to advance progressively and successfully. Patient investigation and carefully conducted experiments were required by the Berlin Admiralty, for these officials believed that unless such research was thoroughly conducted, the building up of any navy and its mercantile marine could only be accomplished after discouragement and possibly disaster had been encountered. Where research had not been conducted disappointment resulted from the construction of vessels which were either faulty in design, ill suited for the purpose intended, or upon which an inferior quality of work had been expended.

For over a hundred years Germany, as a nation, has carried on more original research along technical lines than any other power. While it is true that both England and America have put to practical application the principles discovered by German research, thereby gaining commercial and maritime advantages, it has been the Teuton who has sought after principles, and thus the world is primarily indebted to this studious and thoughtful race for many of the great discoveries and inventions.

THE NAVAL EXPERIMENTAL WORK OF AMERICA AND ENGLAND HAS BEEN OF A SPORADIC CHARACTER.

In a desultory and sporadic manner all naval powers have done some experimental work. It is because original investigation is not always appreciated in its fulness by the Anglo-Saxon that many administrative executive officers are indifferent to such research, and therefore experimental tests in Great Britain and America are not always of a continuing nature. Great Britain, however, has recently been compelled to establish a National Physical Laboratory, because the encroachment of continental rivals threatened to interfere with her foreign markets. It can hardly be said that she has done this work in a manner that should be duplicated by us; since it has been affirmed that in this laboratory the standard measuring machines are installed in a basement room, the walls and ceilings of which are of rough brick, full of deep crevices in which dust can, and will, of course, collect. Better do no scientific work than not do it well, is the maxim of the German.

Thirty-five years ago Engineer-in-Chief B. F. Isherwood, U. S. N., carried on an extended and careful series of experiments in connection with the subject of screw propellers. The information secured at that time is standard authority today, but since then it has required persistent effort to arouse naval administrators to the importance of detailing ships and men for securing data upon questions relating to the action of the screw propeller.

The problem as to whether or not in-turning screws are detrimental to maneuvering qualities would have been solved many years ago if the work planned by Mr. Isherwood had been continued. Our increased knowledge of the theory and practice of screw propulsion since the Isherwood experiments is due, however, almost wholly to the work of Froude, conducted for the British Admiralty. This is confirmatory evidence that such important and difficult work can only be undertaken by official or civilian experts who are able to call upon Government resources for data and information. It requires Government investigation to solve important problems relating to the powering of

vessels, since valuable and far-reaching experiments upon this subject require the use of ships as well as the services of a large number of reliable and competent persons to collect the data requisite for the determination of absolute results.

### EXPERIMENTAL WORK DONE AT THE NAVAL ACADEMY.

With a thorough realization of the importance and necessity of securing data upon screw-propeller problems, the head of the Steam Engineering Department of the U. S. Naval Academy, now Captain C. W. Rae, U. S. N., assisted by the instructors in his department, commenced in 1895 what promised in some respects to be an extended investigation of the problem. These tests were interrupted by the demands of the Spanish-American war, since everything at the Naval Academy had at that time to be subordinated to hastening the graduation of the senior classmen.

The plant consisted of a small triple-expansion engine, turning a shaft upon which was fixed a propeller submerged in a tank of water. This tank was so arranged that the column of water driven forward or back, depending upon the direction of motion of the engine, returned on the opposite side of the tank to the propeller. Between the engine and the tank two dynamometers were placed on the shaft—a direct thrust and a rotary one. Upon a rigidly fixed table, placed over these dynamometers, was attached a recording instrument specially designed by the head of the Department of Steam Engineering. From this simple and yet reliable installation the power developed in the cylinders and that exerted by the propeller could be compared. By noting the thrust upon both the rotary and upon the thrust dynamometers the power expended in frictional resistance could be ascertained, it being represented by the difference in the pressures recorded.

The scope of the experiments embraced the working of propellers of different designs, as regards pitch, area, shape and number of the blades. Thus it was possible to secure absolute comparative data as to the power required to operate the different propellers at varying speeds. It was also proposed to test the

same propellers under different conditions of immersion—which would be from as deep an immersion as the tank would permit to a condition where the blades would be partly out of water.

When Professor Biles, the eminent British naval architect and marine engineer, visited the Academy in 1896, he expressed surprise and satisfaction at finding an installation whose cost was so slight and yet whose capabilities were so vast in securing reliable data upon this important subject.

The head of the Department of Steam Engineering at the Naval Academy at that time had practically but a few hundred dollars as a contingent fund, but with the aid of the machine-shop resources and the inventive genius of his staff of assistants, he showed the character of the original experiments that may be conducted when a well-established laboratory is in operation under intelligent and scientific supervision.

Many more illustrations could be given as to the manner in which important experiments have been discontinued from both necessary and unnecessary causes. It is methodical, thoughtful and persistent work which counts, and as the German excels in this respect, the engineering world is now beginning to understand in its fullness the value of the work done at the German engineering laboratories in promoting German success in both naval construction and maratime development.

### GERMANY APPRECIATIVE OF SCIENTIFIC RESEARCH.

It is an anomaly that the greatest of military nations should be the first to appreciate the scientific attainments and capabilities of the engineer, and it is for this reason that Germany has a start of at least five years over England, France and America in systematic naval engineering research. In all probability each of the three other nations has spent more money than Germany in experimental work, but German expenditure, in great part, has taken place before the article is manufactured or the ship is laid down, while in the case of some rival powers, tests and experiments have been conducted to discover means of overcoming avoidable defects.

RESEARCH SHOULD BE CONDUCTED FOR PREVENTING RATHER THAN REMEDYING EVILS.

The proverbs that "an ounce of prevention is worth a pound of cure" and that "a stitch in time saves nine" are as applicable today as they were in the last century. It is for this reason that the preparatory experimental work conducted by Germany has been productive of greater results than that done by rival powers working in the direction of seeking remedies for existing evils.

The cost to the British Government of using the cruisers *Hyacinth*, *Minerva* and *Hermes* for comparative boiler tests and experiments will approximate more than the cost of establishing and operating both the Charlottenburg and Dresden Stations since their inception. In our Navy it had been suggested to effect a change from in-turning to out-turning propellers of all the battleships and large cruisers in course of construction, without even carrying on a system of comparative tests to find out whether or not the change is desirable. It is illustrations of this character that should cause experts to take an inventory of naval strength by conducting comparative experiments, and thus testing the endurance, efficiency and fighting value of the expensive floating machines that are commonly termed battleships.

AN EXPERIMENTAL STATION OF MORE VALUE THAN A SINGLE BATTLESHIP.

If it be true that the battleship of one generation is the junk-heap of the next, then an economical race like the German is pursuing a wise policy in conducting experimental research and investigation in the direction of finding out how the weak links in the naval chain can be strengthened. In the race for naval supremacy it is bullion, as well as brains, that counts. As the financial budget of Germany may not be as satisfactory as that of England or America, it is imperative upon the part of the Admiralty in Berlin to take good care, even from a financial standpoint alone, that no mistakes shall be made in naval construction.

Experience has shown that the German engineering laboratories are more than a good paying investment, for there is not an expert in that empire familiar with the work being done at these

laboratories who does not believe that their destruction would be a greater national calamity to the Navy and the nation than the loss of one of the battleships of the home squadron. The warship could be replaced in four years. It would take six years to rebuild and put in effective operation the complete installation for conducting experimental research that has been developed and perfected at the Charlottenburg and Dresden technical colleges.

There is probably not an eminent naval or mechanical engineer in America or England who has given consideration to this question who is not also of the opinion that the establishment of a national experimental laboratory for naval purposes will vastly contribute to military strength. Probably the majority of these experts also believe that such an institution would eventually contribute more to actual naval strength than the building of a battleship. One does not need to possess vivid imagination to realize that much is contributed to the fighting strength of a navy by carrying on research along engineering lines, and thus preventing the design, construction and installation of appliances that are ill suited for the purposes intended.

### SPECIAL ENGINEERING FEATURES PROJECTED.

In the preparation of the tentative plans for both the equipment and operation of the laboratory, it has been deemed wise to thoroughly inquire as to what has already been done both at home and abroad. Through correspondence and official visits, the equipment of the leading American institutions has been inquired into. From diploma graduates, as well as from other sources, the Bureau has received valuable information as to the character of the research that is being conducted at the European technical colleges.

The Bureau is particularly indebted to President Henry S. Pritchett, of the Massachusetts Institute of Technology, for a copy of the report of Professor Edward F. Miller of that institution. This technical expert of the faculty had been commissioned by the President and Corporation of the Institute to visit

the most important technical schools of England, Germany, Switzerland and France, in order to report upon their methods of technical instruction and upon their laboratory equipment.

Of late there has been a great scarcity of naval engineering experts available for detail to special duty, and as it was not compatible with public interests to assign an officer to visit the engineering institutions of Europe, the report of Prof. Miller is exceedingly opportune. In some respects it covers the field of information desired by the Bureau as to the development of the purely engineering laboratory on the Continent.

In collaborating the information received from various sources, the Bureau is of the opinion that the laboratory at Annapolis should in many essential respects be patterned after the Charlottenburg school along steam and material-testing lines; after that of Dresden as respects gas-furnace installations and hydraulic appliances; and after the Swiss school at Zurich in the equipment of apparatus for testing that class of turbines which work under low heads.

As for the character of the laboratory building and its furnishing, the technical college at Liverpool should serve as a model, since the building of this institution is an ideal one in many respects, especially as regards light and ventilation.

As there is a growing tendency upon the part of all the technical laboratories both at home and abroad to encourage research work and to teach engineering methods and practices, there should be little time wasted, in encouraging either faculty or students received for instruction, in the effort to acquire manual skill in the operation of tools and appliances, since such work should be the sphere of the manual training school rather than that of a research laboratory.

The museum of the laboratory should contain applications of all the different mechanical movements; every form of quick-return motion; models of various systems of valve gear and linkages; special sets of Reuleaux models, elements of the principal forms of marine boilers, and various designs of steam turbines. In all probability the success of the steam turbine in the future will be a development of a combination of features of several de-

signs rather than the improvement of any one type, and, therefore, special prominence should be given to this subject.

As the success of the laboratory as a whole must be the primary aim, it should be the Director of the Experimental Station, working under the supervision of the Bureau Chiefs, and not the individual heads of special departments, who should determine the character of the work to be done at the laboratory. Probably the special weakness of the German laboratory organization rests in the fact that each particular branch of research work is under a separate head, where every professor in charge is absolutely supreme in his own department. As a consequence, that branch of the laboratory is most developed which has the ablest staff. Such an organization of faculty leads to jealousies among the members, and thus prevents the advancement of the general research work and scientific investigation.

### INFLUENCE OF THE GERMAN TECHNICAL LABORATORIES.

While the experiments conducted at the Charlottenburg, Dresden and Zurich laboratories relate chiefly to improvements in machine design and to the study of the practical application of the principles of kinematics, the work of these institutions has indirectly had a very important bearing upon matters relating to marine engineering. The primary purpose of these laboratories is to give students an opportunity to analyze and report upon the operations of various kinds of machines, pumps, compressors, motors and engines. Experiments and tests are likewise conducted for cheapening the manufacture and improving the character of commercial appliances, particularly in the direction of manufacturing articles that will find a sale in foreign markets.

The more one studies the work done at the German technical laboratories the more impressed he becomes with the thoroughness and patience that characterizes such research. The attention to details, and the conscientious effort to secure absolute information and not to sustain theories, has proved a direct benefit to the extension of the German mercantile marine, by reason of the fact that many German naval architects and marine engineers have received training and instruction in these labora-

tories. Men who receive such training become imbued with the necessity and importance of carrying on comparative experiments in an intelligent, conscientious and scientific manner.

Every national engineering laboratory should set the pace for technical experimental work, and therefore one does not need to possess gifts of prophecy to predict that the engineering laboratory at Annapolis will rapidly develop into an institution that will improve the character of our naval construction if not advance the extension of our merchant marine.

FOR YEARS OUR NEED OF SUCH A STATION HAS BEEN MANIFEST TO NAVAL ENGINEERS.

In 1895, a bill was introduced in the Congress providing for the building and equipment of a naval engineering experimental laboratory at the New London Naval Station. There were many reasons for locating the experimental station in that vicinity, and this site is today the superior one in many respects. When there was a separate corps of naval engineers, however, there were special advantages in having an engineering laboratory located, like that of the War College, at a place entirely distinct from the Naval Academy. With the amalgamation of the duties of the line and engineer officers, Annapolis became the logical place for the establishment of the enterprize, although it is the most ill-suited of all locations if the Academic authorities do not welcome its coming.

For the past eight years, therefore, the Bureau of Steam Engineering of the Navy Department has had in contemplation the establishment of such an experimental plant. The scarcity of officers during the Spanish-American war, and for several years following that event, made it impracticable to urge the measure, but during the intervening time the Bureau of Steam Engineering has made persistent efforts to collect all possible information relating to the subject.

CO-OPERATION OF BUREAU OF NAVIGATION SECURED.

About three years ago the question was carefully considered by Admiral A. S. Crowninshield, and the Bureau of Navigation was induced to cheerfully co-operate in a renewed effort to

have the station authorized by the Congress. Both Secretaries Long and Moody approved the proposition in its entirety. The measure only failed to become incorporated in a previous appropriation bill by reason of the fact that the amendment of the Senate, authorizing its establishment, was stricken out by the naval conferees clearly upon a misunderstanding as to the purpose and necessity for such a laboratory in a modern navy.

It takes time, energy and money to develop such an institution, and therefore the resulting benefits can only be observed after such a laboratory has been in operation for a considerable period. The advance of Germany in naval engineering research will be much more apparent during the next few years than it is now, and it was in recognition of this fact that the Fifty-seventh Congress was induced to authorize the building of such a laboratory for the American Navy. It will be years, however, before the full value of the laboratory may be made manifest to the service at large.

### TOO LITTLE RESEARCH ALONG NAVAL LINES HAS BEEN CONDUCTED.

It can be absolutely stated that the Navy is behind the times in original work and research. Several months ago one of the marine superintendents of one of the Great Lake Transportation Companies told me that if he was called upon to retrench in expenditures the last item to be cut down would be that for experimental purposes, since both the cost of construction and the expense of operation of the steamers under his control had been reduced as a result of the data secured from experimental work. There is not a leading university, large manufacturing concern, nor great transportation company that does not consider it imperative to make tests and experiments. Every navy will also find that it will increase efficiency and promote economy to conduct and to encourage extended investigation of unsolved problems relating to its marine service.

Unless its industrial leaders have acquired a technical and scientific educational foundation, no nation can secure marked advance either in the field of manufactures or in naval construction. The welfare of the technical high schools and scientific

laboratories is likewise dependent upon industrial prosperity, for in times of financial depression there is a tendency to minimize research and investigation. Now that there is a strong sentiment in favor of carrying on naval research, the work should be pushed so that results can be accomplished which would show its imperative necessity to naval development.

A few dollars spent in well-directed and conscientious experiments may result in the saving of hundreds of dollars elsewhere. The cost of maintaining a battleship in commission will approximate $1,000 per day, and warships have been tied up for weeks on account of the corrosion of a few hundred dollars' worth of boiler tubes. It will repay the nation for the cost of an experimental station if the staff of the laboratory will simply cause increased length of life of both boiler and condenser tubes.

### NAVAL ENGINEERING PROBLEMS TO BE SOLVED.

The field to be covered by experimental research along engineering lines is vast. The following are only a few of many urgent problems, in the solution of which the Navy has a direct interest:

1. The value of liquid fuel for various naval purposes.
2. The possibilities of the steam turbine for installation in warships.
3. The efficiency of various forms of propellers.
4. The relative advantages and disadvantages of in-turning and out-turning screws.
5. The reduction of vibration of machinery.
6. Limits of economical increase of steam pressure.
7. The development of practical appliances for utilizing the advantages of superheated steam.
8. A proper ratio of sizes of cylinders for multiple-expansion engines.
9. Improved systems of economy in auxiliary machinery of naval vessels.
10. The value of condensed fuel, such as briquettes, etc.
11. The relative advantages of straight and of bent-tube types of boilers for torpedo boats, gunboats, cruisers and battleships.

12. The corrosion and deterioration of boiler and condenser tubes.

13. The relative value of various alloys for machinery purposes.

14. The types of valve gear most suitable for naval purposes.

15. The endurance of the storage battery and its possible development.

16. The more extensive use of steel castings.

17. The question of lubricants.

18. Calibration of gauges and of instruments necessary for naval engineering purposes.

19. The proportions of centrifugal fans.

20. The most effective systems of forced draft for various classes of warships.

21. Mechanical refrigeration, the present method of cooling magazines being far from satisfactory.

22. Testing non-conducting and fire-proofing materials.

23. The determination by actual test of the best proportions of important engine details.

24. The study of the problem of how to secure more complete and definite information upon trial trips.

25. Reliable form of water-glass gauge that will be applicable for forced-draft conditions as well as when muddy feed water is used.

### PRIMARY OBJECT DESIRED BY ESTABLISHMENT OF STATION—INCREASE OF NAVAL EFFICIENCY.

The primary reason and chief object for establishing the laboratory is to increase the efficiency of the naval service by preventing the adoption on our ships of war of untried or doubtful devices and expedients.

Since it is the aim of many promoters to force their wares upon the Government, every Executive Department should have at its command a laboratory or a station where extended tests could be made for determining the value and usefulness of every appliance submitted for adoption.

A secondary, if not equally as important a reason for establishing the station at the Naval Academy, is due to the fact that

such a laboratory could be utilized for the instruction of the midshipmen. The time has now come when the Naval Academy should be primarily an engineering school, and this should be evidenced by the extent of the installation and the facilities for conducting research, as well as by the character of the instruction imparted.

The experimental station would likewise be valuable for a proposed post-graduate course in engineering. This work is essential to naval efficiency, and is earnestly desired by many junior officers of the service. Post-graduate work in engineering has been recommended by the Academic Board, for this advanced work is absolutely necessary to secure the large completement of engineering experts that will be needed in the near future. If the laboratory will help to provide for this supply, its establishment will be alone justified by giving such experts to the Navy.

### THIS LABORATORY WAS ESTABLISHED AFTER EXTENDED INVESTIGATION AND CONSIDERATION.

The section of the naval appropriation bill relating to the establishment of the experimental laboratory was very carefully discussed in the House of Representatives. On a division, there were 72 votes cast against and 50 for the proposition to have this appropriation form part of the total sum allowed for the rehabilitation of the Naval Academy. Is is quite significant that there was practically no opposition manifested in either the House or the Senate to the commencement of this work, after the purpose of establishing such a laboratory had been understood.

### INTENT OF THE CONGRESS AS TO THE PURPOSE OF THE STATION.

In order that the intent of the Congress may be clearly made known as to its idea of the scope and purpose of such a laboratory, the following statements of the members of the House Naval Committee are herewith repeated, the remarks having been made during the debate upon the naval bill:

Mr. Mudd, of Maryland, said: "The fact of it is, that this building is so far from being any essential part of the Naval Academy that at one time, the gentleman will recall, a proposition was

made to insert the provision in the bill, making the appropriation and authorization, but left the location at the discretion of the Secretary of the Navy."

Mr. Butler, of Pennsylvania, said: "We considered in the Committee on Naval Affairs the importance of this building. It is a beginning, not of more building, but, in my judgment, the beginning of a policy under which the Navy Department will insist on requiring that all men entering the Navy shall become proficient in the art of engineering."

Mr. Dayton, of West Virginia, said: "This is not a building for the training of midshipmen. It is a building and an institution for the purpose of experimenting and testing all the many questions that spring up in marine engineering. It may be utilized for advanced study in marine engineering, but if that course is to be given it will be given to our officers after they have graduated from the Academy. This is simply in line with the school that has been established by the German nation, and which has been found to be of such great advantage to the German navy. In fact, I undertake to say that the German Empire would rather dispense with almost any other institution than its school of engineering at Charlottenburg. This, as I have said, has nothing to do with the Naval Academy. It has been located at Annapolis by the Committee for two reasons: First, because the Government has the land there; second, in order that the midshipmen there may have the benefit of observing the experiments that may be carried on there. Attendance upon such experiments will not be made incumbent on the midshipmen. If any one is to be instructed there, it will be our engineer officers."

Mr. Tayler, of Ohio, said: "The Secretary of the Navy, who was for many years under the tutelage of the same Chairman of the Committee on Appropriations here, obtained and justified his reputation for economic administration of public affairs and the economic expenditure of public money, and I know that no public duty relating to the expenditure of money has lain with greater gravity upon his conscience and judgment than this question of the increase of the amount that should be available for this great improvement at Annapolis.

"Now, this matter for the testing laboratory is entirely independent of the Naval Academy, and was intended originally to be independent of it. So far as Admiral Melville was concerned, and so far as anybody else connected with the Navy Department was concerned, it was immaterial where it was to be put. In the first instance it was thought it was to be put at some other place, but in the latter consideration of it we thought it had better be at Annapolis.

"The Secretary of the Navy insists upon the original plan as proposed. I do not mean the detailed plan, but the general plan of the Naval Academy, requiring the expenditure to be fixed at not less than $10,000.000. This is an entirely different proposition from this provision that we have now under consideration."

Mr. William W. Kitchin, of North Carolina, said: "If gentlemen will read the testimony of the Department they will believe this building ought to be erected. There may be some question as to whether it should be erected at a navy yard or the Academy, but there is no question that Congress ought to settle this matter if we are to have the building."

The project had also been carefully considered by the Senate Naval Committee when the naval appropriation bill of a previous year had been under discussion, the Senate having incorporated an amendment to the bill as it came from the House, making provision for the establishment of such a laboratory. Even up to the closing hours of the first session of the Fifty-seventh Congress the Senate conferees, Senators Hale, Perkins and Tillman, had insisted that the Senate amendment relating to the establishment of a laboratory should prevail.

### THE NAVAL ACADEMY WILL BE A LARGE BENEFICIARY OF THE PROJECT.

The above discussion conclusively shows that the primary purpose of establishing the experimental laboratory was for naval engineering research, and not to form part of the integral course of the Academy training. It will be a valuable adjunct, however, to the educational work of the Naval Academy, and it may not be many years before it may indirectly have a very important influence upon the professional course of instruction.

In recommending that it be established at the Naval Academy, it was the purpose of the friends of the measure to extend the prestige and the influence of the Annapolis institution. There was no desire nor belief that it would in any manner infringe upon the prerogatives or conflict with any policy or official action of the Superintendent or the Academic Board. Its primary work and purpose, however, must be absolutely distinct from the under-graduate instruction of the Academy.

### THE WORK IS NATIONAL IN CHARACTER.

The Bureau of Steam Engineering has been constantly urged to carry on experimental work relating to naval engineering affairs. It can hardly be expected that the shipbuilders, the manufacturers and the technological colleges should be subjected to the expense of conducting tests that are primarily for the benefit of the naval service, when such experiments promise to yield but little financial reward or professional prestige to individuals. It may also be the case that there are military reasons why this information should not be received through others. The expert talent to initiate and to conduct tests will always be available at Annapolis. The needs of the Naval Academy will always require a strong force of able and highly-trained engineer officers, and the senior class might render valuable assistance at times in helping to collect data, for it is certain that some very efficient observers would always be available from those who had aptitude and natural talent for engineering work.

### INDIRECT ADVANTAGES ACCRUING FROM ITS ESTABLISHMENT.

In measuring the benefits that will accrue to the Navy and to the individual officers from the establishment of the station at Annapolis the indirect advantages must also be taken into consideration. There is no doubt but that the shipbuilding firms engaged in naval construction will seek information that could only be secured at such a laboratory. If such information will make the naval ships under construction more efficient and more

enduring, the Government can well afford to furnish the data requested, even though the shipbuilders themselves may reap consequential benefits.

Such an institution will also bring the Naval Academy in closer touch with the technological schools of the country. It is certain that such friendly intercourse will not only materially strengthen the engineering curriculum at Annapolis, but create a greater interest among the universities concerning naval needs and development.

The influence of every university of higher education is most accurately gauged by its relative standing among other similar institutions. It is obvious also that the great universities are judged very much by the character and extent of the original and research work that they undertake. The Naval Academy, therefore, cannot help but be benefited by the proposed engineering-research laboratory. It is for this reason, likewise, that the academic course will be strengthened by being associated more or less with the work of a laboratory which aims to conduct such practical research that our naval engineering plans and specifications will stand as models of their kind.

The station ought also to prove a boon to young and zealous officers. Under existing conditions energetic and studious officers are often discouraged and repressed because there are neither facilities nor funds available to test the merits of plans and inventions submitted by them, and which are strictly naval in character. Surely the inventive genius and the professional aspirations of many officers would be encouraged and expanded by the work of such a laboratory. In the immediate future there ought to be a hundred officers stationed within a few hours' ride of Annapolis who would have a direct interest in some feature of the projected work, and many valuable suggestions would in turn come from such individuals. It has been a great detriment to naval efficiency that an engineering laboratory was not established years ago, for if it had been in operation, there would have been far greater advance in electrical, hydraulic and mechanical engineering, particularly along naval lines.

COMPETENT ENGINEER OFFICERS CAN BE FOUND IN THE NAVY TO CARRY ON THIS WORK.

About twenty-five years ago the Congress of the United States passed a law empowering the President, upon the application of an established scientific school within the United States, to detail an officer from the engineer corps of the Navy as professor of marine engineering and naval architecture at such an institution. As a result of that act, technical education in the United States is greatly indebted to the Navy, by virtue of the splendid work done by the two score officers who were detailed to various scientific schools.

Some of these technical schools were practically organized by naval engineers, and no fewer than four of the leading universities now have as directors of their scientific colleges ex-engineer officers of the Navy. These institutions are Harvard, Cornell, University of Pennsylvania and Ann Arbor, and therefore cordial co-operation with these and other institutions is assured. The opportunity that these officers had of noting foreign industrial and educational methods fitted them admirably for this educational work, and there is no doubt but there are other officers in the Navy who will rise to the responsibility of conducting the proposed experimental laboratory in a manner that will reflect credit upon themselves, the service and the country.

The engineering world is very appreciative of the helpful influence exerted on technical education by engineer graduates of the Naval Academy, and as there are within the service many officers who, by training, education and experience, ought to be qualified for conducting engineering research, there need be no fear that the work of the Navy will not compare favorably in lines of engineering research with that of any other technological institution.

IMPORTANT AND SCIENTIFIC RESEARCH CONDUCTED AT UNIVERSITY OF GLASGOW.

It has been recognized in Great Britain that the reason for Glasgow being the metropolis in mechanical engineering has been due, in great part, to the scientific laboratory attached to

its great University. Upon this subject "Engineering," of London, states:

"It was at this University that James Watt perfected the system of separate condensation without which the steam engine would have been a very expensive appliance. Watt likewise discovered in this laboratory the principle of latent heat, and laid the foundation of an inventive skill which brought forth the steam jacket and other improvements that caused the steam engine to produce power in a more economical manner. It was here that Professor Gordon worked out his formulæ in connection with the strength of columns. The work of the eminent scientists Rankine, James Thomson and Lord Kelvin will ever be associated with the laboratory of this Scotch University."

In strongly urging an appeal for funds to extend the work of the laboratory at Glasgow, "Engineering" further asserted:

"There are many reasons why liberal response should be made, not only by the West of Scotland, but by many others further afield. We could name many instances of works in Britain where a want of knowledge in first principles has led to a great waste of money. The tendency of more class-room training may have the effect of over-confidence in estimating the power to withstand stress, while the practical training alone tends to the opposite extreme. The influence, therefore, of that quickening of observation and of that practical training in the properties of material to be accepted in a laboratory will go some way to insure greater economy.

"It must not, however, be understood that the laboratory can ever give the same training as the workshop. It will, however, prepare the way for that wider experience in the case of students who have not previously been through the mill of practical apprenticeship. It will supply the necessary link between their practical training and their studying of scientific principles and method. In this respect it is indispensable."

## BRITISH OPINION CONCERNING THE VALUE OF NAVAL RESEARCH AND EXPERIMENTS.

It is because there is no better way of showing the value of such a laboratory for naval purposes than by collating the opinion

of some representative engineering experts, that a few extracts from leading technical journals are also incorporated. The following editorial from the "Marine Engineer," of London, will show the trend of British engineering thought with regard to the question:

"It is well known that inventors receive little or no encouragement from the Admiralty, who generally require that an invention must have been thoroughly tested and proved by actual use elsewhere before they will practically consider its utility. This is quite understandable where they have no special staff and establishment where and by whom such proposed novelties could be tested and reported upon, even in their first embryo condition.

"It must be remembered that the present policy discourages the adaptation of inventions to the special needs of the fleet, or forces the more capable and enthusiastic inventors to go abroad or to the States for the development of their ideas as applied to naval subjects. Now, the German Government is much more practical in this respect. There is a naval laboratory established at Charlottenburg, where all new proposals for the benefit of the German Navy can be experimentally tested and the probable advantages or otherwise reported upon, thus clearing the ground, if the report is favorable, for a more extended adaptation in practice.

"The Engineer-in-Chief of the United States Navy is now agitating in his country for the establishment of a similar experimental department at the Naval Academy. What is wanted in the United States is equally required here.

"Such onus of recommendation, and a genuine desire to investigate, can only be expected from a staff which has nothing else to do, and which will only justify its existence as an experimental staff by finding and supporting novel inventions and improvements from time to time.

"Had such an experimental staff and laboratory existed when the adoption of water-tube boilers in the Navy become a burning question, the naval engineers need not have been tied to the adoption only of such a type of boiler as had already a naval

record. The whole question as to type for direct investigation could have been submitted to such a laboratory staff, as has been done later by a specially appointed boiler committee. Much valuable knowledge might thus have been gleaned as to various types of boilers available, irrespective of their naval record, before any considerable adaptations to cruisers had been effected. We do not think, under these circumstances, that the Belleville boiler would have been the type selected."

VIEWS OF PROFESSOR PEABODY, OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

In commenting upon the proposed engineering laboratory, Professor Peabody, of the Massachusetts Institute of Technology, writes:

"The experimental station will have three objects in view:

"(1) The training of midshipmen.

"(2) The training of junior officers.

"(3) The investigation of engineering problems.

"This order is not intended to represent the order of importance in my own mind; I am not sure that I should consider one more important than the others. To my mind the three should be confined in all the work of the station; thus the officers detailed for the purpose should arrange and oversee the experiments, the junior officers should be given responsible charge of individual investigations, and the midshipmen should work under instruction as observers and assistants. Of course, there will be divergence from any such a scheme, but I believe the idea is right."

There need be no apprehension that such a laboratory will turn out too many specialists. The future complaint will be that too few experts are trained. It can be anticipated that some officers who have pursued investigation and original research along special lines will receive inducement to resign their commissions, and thus in laying out the project those interested in the project should anticipate the wants of a future decade rather than the needs of the next few years.

RECENT ENGINEERING EXTENSION AT LEADING UNIVERSITIES.

In connection with the demand for men with engineering training, the following extract from the March number of the the "University of Michigan News Letter" will afford considerable information:

"The demand for engineers throughout America at the present time is far in excess of the supply. Even at this early date, four months before commencement day, many requests for engineers have been received by the heads of the engineering departments of the University of Michigan. Some of these requests have been so urgent as to ask that students be advised to postpone graduation in order that they might take up work at once.

"That this demand for engineers has been felt by other schools of the United States as well as by Michigan is most forcibly shown by some of the appropriations recently received for engineering buildings and equipments by various institutions.

"Not long ago Harvard spent $500,000 for engineering buildings; Wisconsin University recently received an appropriation of $200,000 for the same purpose; the Iowa Agricultural College has built a $200,000 engineering building; the University of Pennsylvania is just about to build a $300,000 engineering building; the University of Illinois has just asked its legislature for an appropriation of $300,000 for the building of engineering and physical laboratories, and the University of Michigan is at present completing a building which, it is estimated, will cost $160,000."

The Stevens Institute of Technology has also received during the past year $225,000 as a special endowment for the support of the Carnegie Laboratory of Engineering.*

CO-OPERATION WITH THE CARNEGIE INSTITUTION IN WASHINGTON SHOULD BE EFFECTED.

In giving $10,000,000 as an endowment fund for an institution which would encourage individual work in scientific investigation, it was undoubtedly the purpose of Mr. Carnegie to include

*The above expenditures are for extensions to the engineering plants of the respective universities.—THE EDITOR.

in the purposes of this gift the promotion of experimental research along maritime and engineering lines. It can certainly be expected that when the Annapolis institution is in operation, that the trustees of the Carnegie fund will find it compatible with the purpose of the donor to encourage civilians, if not individual naval officers, to work in conjunction with the staff of the engineering laboratory at Annapolis.

Now that every nation looks upon the ocean greyhounds as possible scouts in time of war, the mercantile marine has become an important military auxiliary. In the operation of a fleet of battleships it is essential that there should be repair, supply and refrigerating ships, as well as colliers and transports, and, therefore, the logical place for naval architects and marine engineers to work out special problems in connection with the increased efficiency of naval auxiliaries would be at the Annapolis laboratory.

There would be mutual benefits accruing to the naval service and to individual experts if beneficiaries of the Carnegie fund should be permitted to pursue their investigation at the naval engineering laboratory. The individuals would be benefited by reason of the fact that it would not be necessary for them to expend funds for the purchase of instruments of precision that were at the Annapolis institution, and they would also be able to secure conscientious and intelligent observers free of cost. The naval service would derive a benefit by noting the trend of research upon the part of the experts in civil life.

This Government laboratory ought therefore to be open to civilians as well as to officers, especially where the resulting investigations would be conducted at slight cost to the Government.

As it was the particular desire of Mr. Carnegie that the work of others should not be duplicated, and, as the Congress established the Annapolis school for original research, the purpose of both would be well subserved in having the naval engineering laboratory cordially welcome investigators who were conducting research that related to improved economy and efficiency in transportation and in maritime matters, for rapidity of movement of

both men and supplies in time of war now constitute an important military factor.

MODERN INDUSTRIAL CONDITIONS REQUIRE LARGE CORPORATIONS TO MAINTAIN MECHANICAL LABORATORIES.

All of the large industrial and transportation corporations maintain complete testing departments or bureaus of tests, presided over by experts of national reputation who have under them an ample corps of assistants. The work done at these laboratories in advancing and improving the character of railway and manufacturing appliances and in certifying to qualities of purchases has been of great financial gain to the several corporate interests.

If a private corporation finds it essential to maintain such a testing plant, how much more should the Navy—a corporation of far greater size—find the maintenance of such a station profitable for the direct return secured, but likewise necessary for preventing retrogression?

IMPROVEMENT IN ENGINEERING EFFICIENCY OF THE ENLISTED PERSONNEL.

Vessels assigned as training or instruction ships for stokers, machinists, etc., might occasionally rendezvous at Annapolis, in order to assist in particular experiments and to keep in touch with the engineering officers and work of the projected laboratory. Such experiments ought to arouse in the men a greater interest and incentive in naval work, for all would then see and know that the best of apparatus and methods are thoroughly tested before being installed afloat. For an enlisted man to have firm confidence in his ship's armament and motive power is a great gain. Should the "man behind the gun" not have confidence in his weapon, the battle is partly lost. Equally as well, the fireman who faces the furnace must have confidence in the safety and endurance of his boilers, otherwise he will likely fail in doing his full duty in times of emergency.

On board every one of the assigned for the training of the enlisted force of the engine and fire rooms would be warrant ma-

chinists and stokers who were desirous of advancing, and who would, therefore, be receptive for information. Among this class would be found many chief machinists, water tenders and oilers whose services could be utilized for special work. These men would regard it as a post of honor as well as a responsibility to be given such assignments. As such selections would naturally be made from those whose signal ability had indicated to the commanding officers that the naval service would gain by their temporary detail for such work, it would be possible to secure valuable observers from this force.

The possibility of being called upon to take part in valuable experiments would act as a spur to the ambition of the enlisted force. It would be viewed by them as an opportunity to fit themselves for higher work. It would also be regarded as a privilege to be intrusted with the responsibility of helping commissioned officers carry on tests that were asked for by the engineering world.

It would add to the military *esprit de corps* of the engine-room force to be thus designated for work in the naval-military atmosphere of the Academy. Every man on a fighting ship is a combatant, and he should be shown the power and force of the weapons intrusted to his charge.

### THE PROJECTED LABORATORY WILL NOT DUPLICATE THE WORK OF THE NAVAL ACADEMY NOR THAT OF ANY TECHNOLOGICAL COLLEGE.

It should be distinctly understood that the projected laboratory at Annapolis will not in any respect duplicate any of the work done at the Naval Academy. In its scope and purpose it will also be quite distinct from that of any other institution in the United States. The development of the engineering laboratories at Harvard, Yale, Cornell, Ann Arbor, University of Pennsylvania, Massachusetts Institute of Technology and similar institutions are primarily along the line of physical, chemical and technical research. The main purpose of the Annapolis plant will be in the direction of naval engineering development. It is also proposed to conduct special technical investigations, for

which the officers attached to the various naval stations and ships have neither time nor opportunity to undertake.

As it can be expected that the Congress will make liberal annual appropriations for the support and operation of the engineering laboratory, and as there may be occasions when war vessels may be ordered to Annapolis in connection with particular experiments, it ought not to be possible for any other mechanical laboratory in the country to compete with the naval institution in conducting experiments of a strictly marine character.

WHILE EXPERIMENTS ARE COSTLY, THE INFORMATION SECURED WILL BE EXTREMELY VALUABLE.

Some of the experiments will be quite costly, but when the fact is recalled that six boiler firms in Europe and America during the past ten years have expended one-half million dollars in tests and experiments upon marine steam generators, the necessity for naval investigation upon all subjects pertaining to the motive power of warships becomes very apparent. A minimum appropriation of $50,000 should be asked for the first year of the station's existence, and this fact ought to be confirmatory evidence as to the necessity of having the work of the laboratory distinct from the Academy course of instruction.

There would certainly be discrediting of engineering work if it were attempted to have the director of the laboratory, or any of his executive staff, assigned to any other academic duty. It would prove extremely advantageous, however, for some officers connected with the Academy to be detailed for temporary duty or instruction for short periods during special experiments, for such assignments would really be in the nature of post-graduate work. The Bureau regrets exceedingly that the present exigencies of the service now prevent the immediate nomination of an officer for special duty in connection with the work.

It is hoped that within a few months that an officer particularly well qualified for laying out the plant may be recommended for this special duty. It will not only be discrediting the work of the laboratory, but will impair engineering education at the Acad-

emy; to expect any individual officer to carry on systematic original research in addition to other regular duty. The officer who is called upon to lay out the installation may set the pace of the work for the next ten years. This preparatory work is more likely to demand the services of a number of officers rather than one; so that there will be plenty to do in connection with the work for any one man from this time forward.

IT IS THE DUTY OF ALL OFFICERS TO ASSIST IN THE SUCCESSFUL DEVELOPMENT OF THE ENTERPRISE.

The debate in the Congress undoubtedly shows that much is expected from this engineering station. It would only arouse resentment of influential personages if any action should be taken which could be construed as discriminating against such research. It has necessitated a campaign of education to secure the establishment of the station, and it will succeed if there is detailed an adequate and efficient complement of officers for duty in connection with the proposed experimental work.

This engineering laboratory will not encroach upon excellent work done elsewhere, and thus the directors of engineering research at the leading technological universities cordially approve the establishment of the Government plant. Of necessity the work done at the several educational universities must be preeminently in the more general line of physical investigation, while the research at Annapolis will be primarily in the direction of advancing naval engineering efficiency and endurance, and thus co-operation ought to be secured.

ALL BUREAUS OF THE NAVY DEPARTMENT WILL FIND THE STATION OF VALUE FOR RESEARCH.

Since the station will conduct engineering research that will add to the general fighting efficiency of the ship, it will be but a few years before it will be as valuable an auxiliary to the chiefs of Bureaus of Ordnance, Equipment and Construction as it is to steam engineering. There is no doubt but that in the early future the ordnance demands of the Navy will compel the transfer of the experimental basin at the Washington gun foundry to An-

napolis, as an adjunct to the projected laboratory. The work of the engineering laboratory will be of such broad character that it will not be conducive to naval efficiency and economy to maintain independently an expensive experimental basin that is limited in its scope. It is important to determine the best form of hull. It is of far greater moment to extend the broader project of a naval engineering laboratory, whose scope and purpose comprehend not only improvement in the design of hull, of machinery and of auxiliaries, but also of the gun and its mount, as well as in armor and its attachment—in other words, the experimental engineering project makes for increase of efficiency and endurance throughout the ship.

### VALUE OF A CENTRALIZED NAVAL-RESEARCH LABORATORY.

This centralization of experimental work along naval lines has appealed so strongly to British naval experts that in commenting upon the proposed station at Annapolis, "The Engineer," of London, has editorially stated:

"When we say that what he (the Engineer-in-Chief of the U. S. Navy) wants—and what the British Navy wants—is not a laboratory full of apparatus and students and experts, but an experimental board, or bureau, or committee—the name matters nothing—to carry out inquiries. The laboratory, properly so called, would be then little more than a species of head office or center from which the operations of the committee could radiate.

"We are fully persuaded that something like the amount, $400,000 (asked for by the Bureau of Steam Engineering), could be spent every year for several years to come by the Engineer branch of the British Navy, and that with the utmost benefit. We spend large sums now. The trials of the *Minerva* and *Hyacinth* were not carried out for nothing. The investigation of the strength of the hulls of torpedo destroyers will be costly. Various inquiries of the kind could be mentioned. These are all good in their way; but their value would be augmented and their cost reduced if there was some specially constituted body to organize investigations and carry out experiments in a sys-

tematic and orderly fashion. * * * Is it too much to hope that Great Britain may do still better, and that a Board of Experiment will yet form a constituent department of the Admiralty?"

THE BRITISH ADMIRALTY LIKELY TO INSTALL A LABORATORY OF A SIZE COMMENSURATE WITH ITS NEEDS.

The above declaration is very significant, particularly in view of the fact that the British Admiralty is about to follow our action in this respect. The new British Admiralty scheme of training officers for the Royal Navy is a development of our naval personnel law. It is probably an improvement, because it not only demands a longer time for training and a younger age for entry into the service, but because it also provides for compulsory duty in the engine room.

From authoritative sources I have learned that the naval engineering laboratory project has appealed very strongly to many experts in the British Navy, and that the principal fault found with the American installation is that it is proposed to establish it on too small a scale. The fact that British experts suggest an annual expenditure about equal to that requested for the installation and equipment of our plant is conclusive evidence that, as their demands are greater, they mean to surpass us in the character of the equipment of their laboratory for naval research.

It should be stated that in asking for $400,000 for buildings and equipment, I only requested an amount sufficient to show the imperative necessity of such a station, and it is my belief that the results accomplished will soon cause the Congress to grant liberal appropriations for the extension of the work.

THE ELEMENT OF TIME OF EXTREME IMPORTANCE IN GETTING THE PROJECT UNDER WAY.

There is no reason why actual work should not commence on the laboratory building before the end of the year. As there is an urgent necessity for the commencement of experimental research along naval engineering lines, the work of establishing the plant should be pushed with vigor independent of all other

extensions and improvements projected at the Naval Academy. Any unnecessary delay in preparing plans, advertising for bids, awarding contracts, or in actually commencing work will invite bitter criticism and official complaint.

While the authorization for this work is absolutely independent of the rehabilitation of the Academy, there is no reason why it should not supplement many features of the Academy. While the Bureau is specially desirous that the architecture of the laboratory shall conform to that of the other buildings projected at Annapolis, it will likewise take special care that its construction shall not be delayed by work upon other structures, since the project is absolutely independent of the rehabilitation of the Academy. The purpose of establishing this laboratory is as important as any special feature of the work connected with the rehabilitation of the Naval Academy, and therefore there should be no necessity for either work to interfere with that of the other.

### THE VALUE TO THE INDUSTRIAL WORLD OF EXPERIMENTS AND OF TESTS CONDUCTED UNDER NATIONAL AUSPICES BY DISINTERESTED EXPERTS.

While important and far-reaching experiments have been conducted at the mechanical laboratories of the leading technological universities, the scientific and industrial world has been too well aware of the fact that the fund available by the educational institutions for engineering experiments has been but a small percentage of that allowed for physical research. Then, again, it has sometimes been believed that some of the individual experimenters have had preconceived opinions upon certain questions, and that only sufficient tests were conducted by them to sustain their particular contentions.

In fact, it has now become so easy to secure individual expert support to all phases of technical controversies that a great jurist recently asserted that he had about come to the conclusion that the character of expert evidence submitted is often in harmony with the views of the person who can pay the highest fee demanded.

When tests are conducted, however, under Government auspices it has been a general rule to permit all directly interested in the experiments to examine records, and even to make copies of all documents that are not of a military nature. The professional reputation and even the commissions, as well as the prestige of the Government experts, are thus at stake, and must act as deterrents to careless or ill-considered reports concerning experimental research.

The results of many of the engineering tests upon special subjects conducted under the auspices of the Bureau of Steam Engineering have stood and will remain as standards in engineering literature. One has only to remind the technical world of the fact that it was a board of naval engineers which practically secured the adoption of an American standard of screw threads. It was naval experimental research which gave the world the navy-bronze, which is to-day the best all-around alloy for machinery work. It was naval investigation which caused the standardization of indicators and steam gauges. It was naval research that first impressed the industrial world with the possible economies that could be secured by utilizing to a greater extent the expansions from high pressures, as well as by superheating the steam.

The notable series of experiments that have been conducted during the past two years by a board of naval experts, in securing comparative data as to the relative efficiencies of various coals and oils as combustibles, will be of incalculable benefit to the maritime and to the manufacturing world.

In general, naval engineering experiments that have been of an extended nature stand today unimpeached, practically standard in value, and regarded by the industrial world as data collaborated by capable experts of integrity and ability. With a well-equipped plant, and with liberal annual appropriations by the Congress, it can be expected that such a laboratory will not only prove a valuable military adjunct, but that Annapolis will become a center of engineering research for the mechanical world.

It was simply because the country at large did not possess a national university of research that Mr. Carnegie was induced to

munificently establish an institution which would cover a field that had never before been occupied. If original investigation and research is worthy of the bounty of a private individual, surely a laboratory that makes for research that will increase naval efficiency is entitled to departmental encouragement and approval, as well as Congressional support.

ENGINEERING SENTIMENT AND INFLUENCE CAN BE DEPENDED UPON TO SUPPORT THIS LABORATORY.

It is said that sentiment rules the world, and one cannot read the Congressional debates upon the proposition to establish this laboratory without fully appreciating the fact that regard and sympathy for things engineering was a considerable factor in securing the funds requisite for the building and the equipment of the plant.

The sentiment in behalf of the force working beneath the protective deck of our warships is very deep seated. It not only exists in Congressional and in journalistic circles, but is implanted in the hearts of a large majority of the people at large. There is, therefore, in the word "Engineering" a power and force that may be very momentous for good or for evil to the Executive branch of the service.

The Academic board at the Naval Academy has only to give moral encouragement as well as cordial and official recognition to the purpose and work of this station to secure the gratitude and support of the engineering fraternity of the country. This may mean much for the Naval Service in the future. By reason of the present industrial prosperity of the country the appropriations for the support of the naval establishment are now given very cheerfully, but the time may not be far distant when there will have to be retrenchment, and the friends of engineering at that time will be found no small factor either in numbers or in influence in preventing the Navy from being crippled.

It is certain that the standard which the Navy at large places upon engineering work will be evidenced by the interest taken in this project by officers stationed at Annapolis. Surely the Line of the Navy will not make foes of those who desire to be its

friends, and therefore the establishment of the laboratory should be regarded as an important project—in fact, a means of putting into practical effect the spirit and purpose of the personnel law.

While it is true that the amount authorized for construction and for equipment of the laboratory is but four per cent. of the appropriation made for the rehabilitation of the Academy, it is equally true that there are members of both the House and the Senate Naval Committees who believe that the results secured from the naval engineering plant will surprise the service at large. The project has too many powerful friends not to succeed. It can be made a tower of strength to the Line of the Navy if it is given the same support and encouragement that has been accorded the Torpedo School and the Naval War College.

# THE OFFICIAL TRIAL OF THE U. S. S. *FLORIDA.*

By Lieut. Commander Albert Moritz, U. S. Navy, Member.

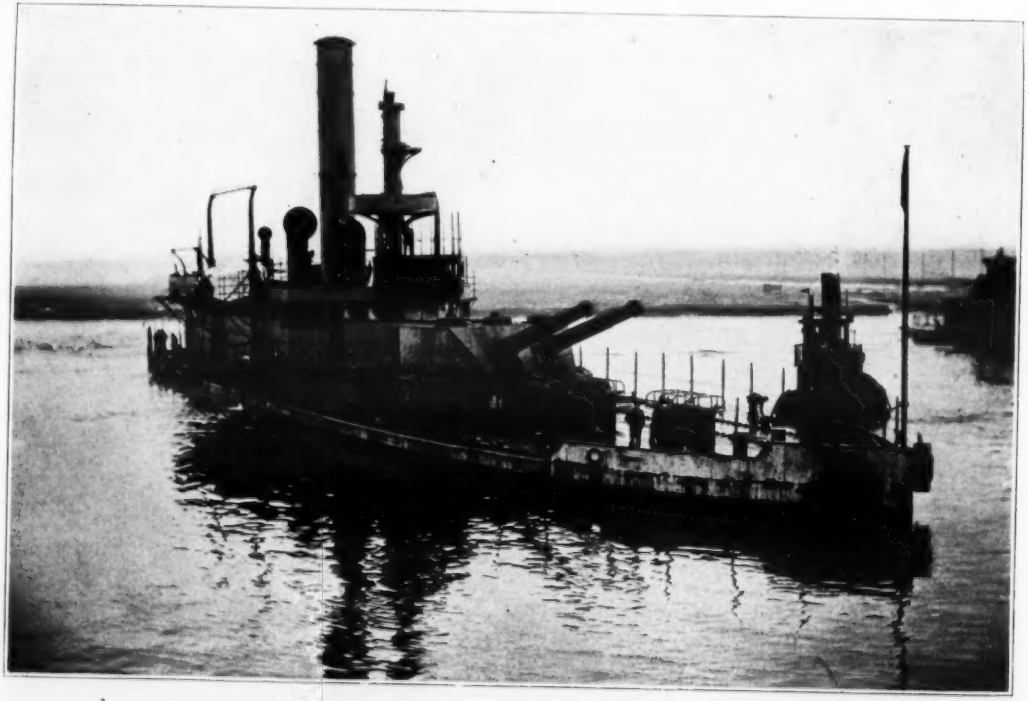
---

The *Florida* was built at the Crescent Shipyard, Elizabeth, New Jersey, being one of the four monitors the construction of which was provided for by Act of Congress, approved May 4, 1898. She does not materially differ from the other three, except in the design of the boilers.

The contract was signed October 11, 1898; the vessel to cost $825,000 and to be completed in twenty-four months; the speed to be not less than 12 knots. A supplementary contract was signed December 9, 1898, in which the length of the vessel (originally 225 feet) was to be increased by 27 feet. The cost was increased to $925,000 and the time for completion extended to twenty-nine months, the speed requirements being reduced to 11½ knots. The increase of length was mainly taken up by the athwartship coal bunkers.

The first keel plate was laid in February, 1899, and the vessel was launched with all machinery on board, except main engines, on Saturday, November 30, 1901. Mrs. Lewis Nixon, a native of the State of Florida, wife of the builder, was the sponsor.

The ordnance and equipment, not supplied by the contractor but furnished by the Government, consisted of the battery and ammunition supply, the armor already drilled and fitted, and armor bolts (not including the main-deck plating), the boats and their spars, blocks, portable furniture, mess tables and benches, cooperage, anchors, chains, cables, and various other articles of equipment. The contractor was required to put these appliances in place.



U. S. Monitor "Florida" off Elizabethport, N. J., March 5, 1903.

HULL DIMENSIONS.

| | |
|---|---|
| Length between perpendiculars, feet | 252 |
| over all, feet and inches | 257- 3¼ |
| Beam, extreme, feet | 50 |
| at load water line, feet | 50 |
| Ratio of length to beam | 5.04 : 1 |
| Depth (molded) from top of main-deck beams at side to bottom of frames at midship section, feet and inches | 14-11½ |
| Height of superstructure above main-deck beams to bridge deck, feet and inches | 14- 6½ |
| Draught, normal, mean, feet and inches | 12- 6 |
| Displacement according to normal draught, tons | 3,225 |
| per inch at load water line, tons | 25.38 |
| Area of immersed midship section, square feet | 600 |
| Center of gravity of load water-line plane aft of midship section, inches | 6½ |
| Center of buoyancy above bottom of keel, feet and inches | 6-10¼ |
| forward of midship section, feet and inches | 3- 1¼ |
| Transverse metacenter above center of buoyancy, feet and inches | 16-10 |
| Longitudinal metacenter above center of buoyancy, feet | 390 |
| Coefficient of fineness on extreme dimensions | .70 |
| of midship section | .96 |
| load water line | .84 |
| Cylindrical coefficient | .70 |
| Number of frames | 82 |
| watertight compartments | 135 |
| watertight doors, including those of long-arm system | 56 |
| watertight doors, long-arm system | 21 |

DETAILS OF HULL CONSTRUCTION.

*Flat Keel.*—Made of two thicknesses, inner course of 20-pound plates, outer course of 25-pound plates.

*Vertical Keel.*—Thirty inches in depth throughout, except at ends, of 20-pound plates.

*Docking Keels.*—Extend from frame No. 21 to frame No. 64, parallel to center line, made of teak wood 12 inches wide, 4½ inches thick amidships, 1 foot 3 inches thick forward, and 1 foot 11½ inches thick aft. A 10-pound steel wearing strip is placed on the bottom side of keel.

*Stem.*—Cast steel, single casting; weight, 6,782 pounds.

*Ram Plate.*—Thirty-pound plates extending from stem to bulkhead No. 6. Form of ram and stem is shown in Fig. 1.

*Stern Post.*—Cast steel, single casting; weight, 10,750 pounds.

*Rudder, not Balanced.*—Frame of cast steel, filled with white pine, covered with 10-pound plates; least diameter of head, 12 inches, exclusive of brass sleeve. Weight complete, 10,124 pounds.

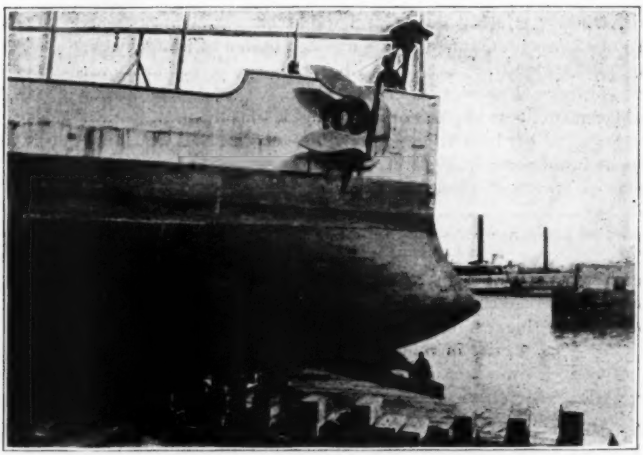


FIG. 1.—U. S. MONITOR "FLORIDA," BOW VIEW.

In Burlee Drydock, Port Richmond, Staten Island, N. Y., February, 1903.

*Longitudinals.*—First and second, 12½-pound plates extending from frame No. 6 to frame No. 82. Third, 15-pound plates extending from frame No. 13 to frame No. 73. Fourth, 12½-pound plates extending from frame No. 18 to frame No. 67.

*Outer Plating.*—Twenty-pound plates from flat keel to armor shelf.

*Inner Bottom.*—Extends from frame No. 6 to frame No. 77. From frame No. 18 to frame No. 69 it is of 12½-pound plates; forward and abaft of frames No. 18 and No. 69 it is of 10-pound plates; the center course is of 15-pound plates.

*Beams.*—Bridge deck, angle bars, 4½ by 3 inches; 9.1 pounds per foot.

Superstructure deck, angle bulb, 7 by 3 inches; 18¼ pounds per foot.

Main deck, angle bulb, 10 by 3½ inches; 26.5 pounds per foot, except forward of frame No. 6, where they are 8 by 3½ inches; 19.23 pounds per foot.

Berth deck, angle bar, 4½ by 3 inches; 9.1 pounds per foot.

Berth deck is cambered 2 inches in 50 feet.

Main, superstructure and bridge decks are cambered 9 inches in 50 feet.

*Reverse Bars.*—The reverse bars are worked continuously from the fourth longitudinal to the armor shelf of 4 by 3 inches, 9 pounds per foot; below the fourth longitudinal, instead of the regular reverse bar, halfstaple-shaped bars are worked between the longitudinals and vertical keel of 3 by 3 inches, 7 pounds per foot. Extra double reverse bars are worked under the engines and boilers.

*Material.*—Is of mild steel, of domestic manufacture, conforming to the requirements of "Specifications for the inspection of hull material for vessels in the U. S. Navy," approved by the Secretary of the Navy June 6, 1898.

*Bridge Deck.*—On this deck are located the pilot house, three 6-pounder semi-automatic, and two 1-pounder automatic guns, the after searchlight and the boats. Two 26-foot cutters are carried in cradles, one on each side, aft; and one 28-foot steam cutter, one 28-foot launch and two 28-foot whale boats are carried at the davits. An 18-foot dinghy is stowed inside the launch. There is a double steam winch on this deck for hoisting the boats. Just abaft the conning tower and pilot house is a military mast, in the top of which are mounted two 1-pounder automatic guns. A platform above the fighting top, forward, carries the forward searchlight.

*Superstructure Deck.*—On this deck are located four 4-inch rapid-fire guns, arranged at the corners of the superstructure so as to give the forward guns an angle of fire of 135 degrees and the after ones 165 degrees. There are also two 1-pounder automatic guns, one on each side, aft of the conning tower, as well as the galleys and the drying room.

*Main Deck.*—On this deck, forward of the superstructure, are

the 12-inch turret and the windlass. Within the superstructure are the lavatories, showers, a large portion of the crew's space, captain's day cabin, officers' quarters, wardroom, pantries, engineer's log room, and offices of the executive officer and the paymaster.

*Berth Deck.*—On this deck are the sick bay, prison, machine shop, storerooms, berthing space for a portion of the crew, dynamo room, staterooms of the captain and the wardroom officers, and the steering room. A wing passage on both sides of the ship extends from the dynamo room aft to the athwartship passage at frame No. 66.

*Hold.*—Below the berth deck are the magazines, shell rooms, storerooms and the two forward coal bunkers, the arrangement of spaces being indicated in Fig. 2.

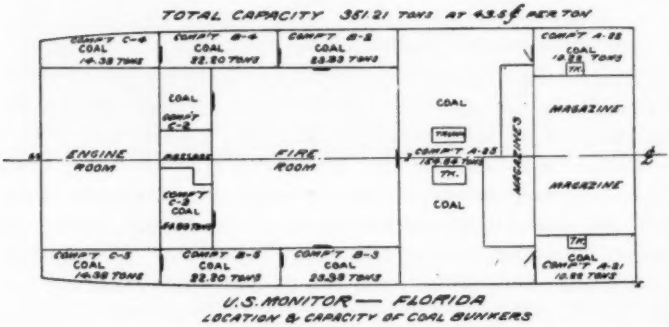



FIG. 2.

*Drainage System.*—The main drainage is of galvanized steel, 11 inches in diameter, and runs from the boiler room to the engine room, having branches in the latter compartment connecting it with each circulating pump. It is also provided with connections to the fire and bilge and auxiliary feed pumps, and is fitted with the necessary non-return valves. For the auxiliary drainage four manifolds are fitted in convenient places, with suction pipes leading to the double-bottom compartments, trimming tanks and sea connections. All manifold valves are worked from the manifolds direct.

*Armor.*—The water-line belt is vertical and extends the entire length of the ship, 2 feet 6 inches above and 2 feet 6 inches below the water line. In wake of the engines, boilers and magazines the armor is 11 inches thick at the top and tapers to 5 inches at the armor shelf. Forward and aft of this the thickness is reduced to 7 inches at the top and 4 inches at the shelf, while at the extreme ends of the ship the top and bottom thicknesses are 5 inches and 3 inches respectively. The conning tower is circular, 5½ inches thick on the forward side and 5 inches thick on the after side, and there is an armored tube 3 inches thick leading from it, in which are carried telegraphs, steering shaft, etc. The smoke pipe and ventilator have armor 5 inches thick, extending 4 feet above the main-deck armor. The main-deck armor is 1½ inches thick, and consists of two 30-pound plates. The barbette for the 12-inch guns has armor 11 inches thick in front and 9 inches thick in the rear. The front plate of the turret is inclined, and is 10 inches thick; the other turret plates are 9 inches thick.

*Armament.*—The battery consists of two 12-inch, Mark III, breech-loading rifles, mounted in a balanced turret, on the center line of the ship, forward of the superstructure; four 4-inch, Mark VII, rapid-fire guns, mounted on the superstructure deck; three 6-pounder, semi-automatic rapid-fire guns; four 1-pounder (heavy) automatic guns; two 1-pounder Hotchkiss, heavy, Mark II, and two Colt's automatic guns .30 caliber, mounted on the superstructure and bridge decks, and in the military top. Small arms are supplied as follows: 80 rifles, .30 caliber; 2 rifles, 22 caliber; and 60 revolvers, .38 caliber.

### INTERIOR COMMUNICATIONS.

*Mechanical Gongs and Telegraphs.*—The gongs are located as follows:

One 8-inch gong at anchor windlass, with pull at each side in bow on main deck.

One 8-inch gong at bottom of ash-hoist trunk, with pull at ash-hoisting engine.

One 18-inch gong for each engine, placed on bulkhead forward

of engines, with pulls for each aft on the bridge deck and abaft of the pilot house on the same deck.

There is a repeating mechanical telegraph of Cory & Son's design for each engine, connecting to transmitters in the pilot house and conning tower.

There is also fitted a repeating telegraph, with gong and dial, between the engine and fire rooms.

Mechanical tell-tales, of the contractor's design, showing the direction of motion of the main engines, are located in the pilot house and conning tower. In the engine-room the tell-tale hands, red for port and green for starboard, are on one common dial, for the purpose of showing the relative speed of the two engines.

*Voice Tubes, Call Bells, Push-Buttons and Annunciators.*—There is a system of voice pipes, with call bells, between the various parts of the ship. The leads to the pilot house and conning tower are provided with a special three-way cock in conning tower for cutting out either station. There is a system of push-buttons leading to annunciators in the ward-room officers' and captain's pantries, also to the captain's orderly. A 10-inch single-stroke gong for boat-hour call, with push-button on main deck, is installed in passage near the officers' quarters on the berth deck. The annunciators are of the improved gravity drop type, and are fitted for voice pipes, call bells, telephones and for the fire-alarm system.

*Telephones.*—There are six telephone sets installed at the following stations: pilot house, conning tower, turret, dynamo room, captain's stateroom on berth deck, and steering-engine room. The telephone used is the "Bell Telephone Company's No. 4 N. W. T. Marine Set." There are two independent circuits, calling and talking. There is no central station.

*Fire Alarms.*—There are mechanical thermostats in the coal bunkers and magazines, connected with a 28-drop annunciator in passage on the berth deck, near the captain's cabin. The thermostats in the bunkers are set to operate at a temperature of 200 degrees Fahrenheit; those in the magazines at 110 degrees Fahrenheit.

*Watertight Doors (long-arm) Alarm.*—The warning system for

closing watertight doors consists of a switch in the pilot house and solenoid whistles, there being two on the main deck and six on the berth deck.

*General Alarms.*—This system consists of four alarm switches, located as follows: pilot house, conning tower, executive officer's stateroom and captain's stateroom. These switches operate eight 12-inch electro-mechanical (clock-work) gongs, there being five of these on the berth deck, two on the main deck, and one in the engine room.

*Electric Engine Telegraphs.*—These are of the illuminated-dial pattern, and will signal changes from "1" to "4." There is an indicator on each engine, each connecting to a combined indicator and transmitter in the pilot house and the conning tower. The indicators on the engines have a magneto bell placed on the back.

*Steering Telegraphs.*—These are of the illuminated-dial pattern, and will signal "Steady" and "0", white light; "5", "15" and "35" (degrees) starboard, green light; "5", "15" and "35" (degrees) port, red light. Indicators are located in the steering-engine room. Combined transmitters and indicators are located in the pilot house and the conning tower.

*Helm Angle Indicator.*—These are of the illuminated-dial pattern. The transmitter is located in the steering-engine room at the rudder head to which the contact maker is secured. There are indicators in the pilot house and conning tower, the dials of which show on each side of the center "$2\frac{1}{2}$", "5", "$7\frac{1}{2}$", "10", "15", "25" and "35" degrees, with green light for starboard and red light for port. The figure "0", at center, has a white light.

*Revolution Indicators—Electrical.*—These consist of a porcelain dial, in case, with plate-glass face, for each engine, and are located in the pilot house and the conning tower. Two small indices point to the words "Ahead" and "Astern" on each dial. These are operated by electrical connections made on the thrust shaft in the shaft alley, and show the direction and number of revolutions.

## VENTILATION.

The hull ventilation is accomplished by means of eleven General Electric Company's blowers, some of steel plate and others of cast shell design, as follows:

Two ¼-H.P. 80-volt shunt-wound motors direct connected to No. 3 monogram blowers. These are located in the steering room.

Two 1-H.P. 80-volt motors direct connected to 30-inch steel plate fans, these being located at the after end of the fore-and-aft passages on the starboard and port sides of the ship.

Two 1-H.P. motors direct connected to 30-inch steel plate fans located upon the main deck.

Four 2½-H.P. motors direct connected to 40-inch steel plate fans located near the dynamo room.

One 5-H.P. motor direct connected to 55-inch steel plate fan for the ventilation of the engine room.

### ELECTRIC PLANT.

The electric light and power equipment of the *Florida* is entirely furnished and installed by the General Electric Company, and consists of generators, incandescent lights, searchlights and power apparatus. There are four generating sets, each of 32 kilowatts capacity, compound wound, running at 80 volts, 400 ampères. Each of these sets is self-contained and is driven by steeple compound engine, cylinder diameters 9 and 15 inches by 6-inch stroke, running at 400 revolutions, with 100 pounds of steam. Each of these generating sets is arranged for use in turning the turret. The switch board in the dynamo room distributes currents for the various motors, lights, searchlights and turret turning. Each dynamo can be connected, when required, to either or all of these sections. The lights are as follows:

Two hundred and fifty-nine 16-candlepower incandescent lamps operated upon 12 separate circuits.

One night signal set.

Two 24-inch searchlights.

Two cargo reflectors.

Diving lamps and running lights.

One of the searchlights is mounted upon a platform on the mast above the military top, and the other aft on a platform on the bridge deck. The projectors are 24 inches in diameter and

are hand controlled. The lamps are of the horizontal type, with combination hand and automatic feed, and are designed for a current of from 40 to 50 ampères, with a difference of potential of about 48 volts across the arc.

The signal set is the Ardois night signal set, and consists of four double signal lanterns and a pivoted key board, this last being on top of the pilot house.

The motors on the ship are located as follows:

*Turret.*—Two 35-H.P., 400-R.P.M., 80-volt shunt-wound motors operated upon variable voltage system, each capable of turning the turret, although ordinarily they are coupled together. These are located in the turret and revolve with it. They are controlled by a controller supported under the turret and operated from a handle in the central sighting hood between the 12-inch guns.

There are two 12-inch car ammunition hoists, each operated by a 25-H.P. 80-volt shunt-wound motor running at 270 R.P.M. These motors are located between the girders under the 12-inch guns and are controlled by controllers in the turret near the breeches of the guns.

The guns are elevated by means of two 3½-H.P. 80-volt series-wound motors running at 400 R.P.M. These motors are located in the center girders, and are operated by controllers located at the sighting hoods outboard of the guns.

The rammers are located behind the guns, each driven by a 5-H.P. series-wound 80-volt motor running at 375 R.P.M., and operated by a controller supported on the top of the rammer.

There is a ½-H.P. direct-connected motor operating a No. 2 monogram blower, this set being supported at the top of the turret and arranged to drive the smoke out of the turret.

*Chain Ammunition Hoists.*—There are four chain hoists, each operated by a 5-H.P., variable-speed, 80-volt shunt-wound motor having a maximum speed of 1,070 R.P.M. Each of these is supplied with a General Electric U. S. controlling panel. Two of these hoists are forward and two aft.

ELECTRIC MOTORS—TABLE FOR WORK UNDER NORMAL CONDITIONS.

| Name. | Number. | I.H.P. | R.P.M. | Volts. | Ampères. |
|---|---|---|---|---|---|
| Turret turning | 2 | 35 | 400 | 80 | 370 |
| 12-in. ammunition hoist | 2 | 20 | 270 | 80 | 210 |
| 12-in. elevating | 2 | 3.5 | 400 | 80 | 45 |
| 12-in. rammer | 2 | 5 | 775 | 80 | 60 |
| 4-in. chain ammunition hoist | 2 | 5 | 1,070 | 80 | 57 |
| 6-pdr. chain ammunition hoist | 2 | 5 | 1,070 | 80 | 57 |
| Smoke blower in turret | 1 | .5 | 1,750 | 80 | 5 |
| No. 3 blower in steering engine room | 2 | .75 | 1,350 | 80 | 7 |
| 30-in. steel plate fan | 4 | 1 | 1,100 | 80 | 10 |
| 40-in. steel plate fan | 4 | 2 | 822 | 80 | 22 |
| 55-in. steel plate fan | 1 | 5 | 602 | 80 | 42 |
| Air compressor motor of long-arm system | 1 | 7.5 | 950 | 80 | 81 |

MAIN ENGINES.

There are two three-cylinder triple-expansion engines of the vertical, inverted, direct-acting type, placed opposite each other in the same watertight compartment, the H.P. cylinder of each being forward. The cylinders of each engine are supported by three front and three back columns; the front columns are of forged steel of cylindrical section, and the back columns are of cast iron, cast in with the condenser sections. The arrangement of engines and boilers in the compartments is shown in Fig. 3.

The bedplates are of cast steel, and consist of six cross girders of I section and one longitudinal girder of ∩ section, with stiffening ribs.

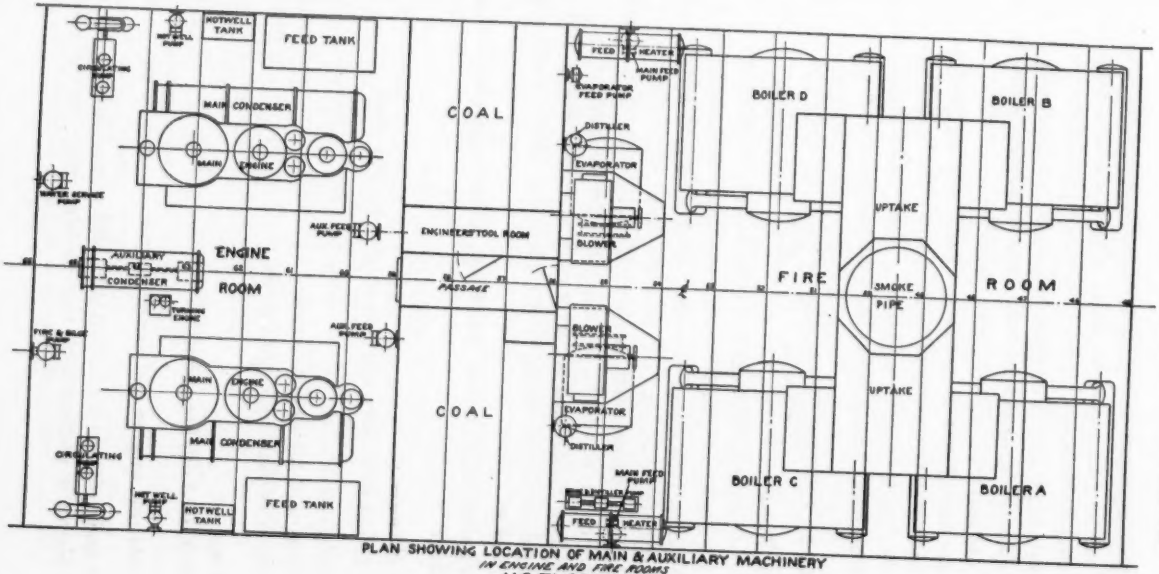
The H.P. valve chest of each engine is fitted with one piston valve, the I.P. valve chest with two piston valves and the L.P. valve chest with a double-ported slide valve. The L.P. valves only are fitted with balance pistons.

The link motion is of the double-bar Stephenson type; all valves being worked direct, with one crosshead for the I.P. valves.

Adjustable cut-offs are fitted to each link, with a range of from five-tenths to seven-tenths stroke.

All cylinders are jacketed around the working linings.

The throttle valve of each engine is balanced by a piston working in a cylinder forming part of the throttle-valve casing, steam being admitted to the back of the balance piston by means




PLAN SHOWING LOCATION OF MAIN & AUXILIARY MACHINERY
IN ENGINE AND FIRE ROOMS
U.S. FLORIDA.
FIG. 3.

of a by-pass pipe and valve. The throttle valves are operated, through levers and screw, by hand wheels which are provided with locking devices.

The main and auxiliary steam pipes are of lap-welded mild steel; auxiliary steam pipes of less than two inches diameter are made of copper.

The lubricating system consists of a distributing tank for each engine, with pipe connections to the manifolds, furnishing oil to the moving parts of each cylinder. The distributing oil tanks are filled by hand pump from the main storage tanks.

CAPACITY AND LOCATION OF OIL, SODA AND TALLOW TANKS IN ENGINE ROOM AND FIRE ROOM.

*Engine Room—*

One 50-gallon tank, cylinder oil, after bulkhead amidship.
Two 135-gallon tanks, lard oil, after bulkhead outboard, S. and P.
Two 82-gallon tanks, lard oil, side bulkhead aft, S. and P.
Two 10-gallon tanks, lard oil, side bulkhead, aft, S. and P.
Two 5-gallon tanks, lard oil, under deck, over L.P. cylinder valve chest, S. and P., to supply engine oil boxes.
Two 3-gallon tanks, lard oil, after ends of feed tanks, S. and P.
Two 5-gallon tanks, soda, under platform, above condensers, S. and P.
One 50-gallon tank, tallow, amidship, under engine-room hatch ladder.

*Fire Room—*

One 3-gallon tank, lard oil, side of port blower shelf.

*Summary—*

| | |
|---|---|
| Ten tanks, lard oil, engine room, . . . | 470 gallons. |
| One tank, cylinder oil, engine room, . . | 50 gallons. |
| Total oil, . . . . . | 520 gallons. |
| One tank, lard oil, fire room, . . . . | 3 gallons. |
| Total oil, engine and fire rooms, . . | 523 gallons. |

The main pistons are of cast steel, dished and finished all over. Each piston is packed with two packing rings set out by steel

springs. The piston rods are hollow, of forged nickel-steel, oil-tempered and annealed.

The connecting rods, with their caps and bolts, are of forged nickel-steel, oil-tempered and annealed. The crosshead end of each rod is forked to span the crosshead, the wrist pin being shrunk in and secured against turning by screw keys.

The body of the crosshead is forged on the piston-rod end, and a manganese-bronze slipper lined with anti-friction metal is bolted to its under side.

The crosshead guides are of cast iron and are secured to the back columns. The guides are cored out on the backs and fitted with steel waterbacks forming passage for the circulating water. The backing guides are also of cast iron, and are bolted to flanges provided for that purpose on the go-ahead guides.

The eccentrics are of cast iron, those of the high pressure being solid, and those of the I.P. and L.P. being in two parts. Each backing eccentric is securely keyed on the shaft, and each go-ahead eccentric is secured to the corresponding backing eccentric by a through bolt in a slotted hole.

The eccentric straps are of composition faced with white metal, and the eccentric rods are of forged nickel-steel. There is for each engine a steam float-lever reversing engine with hydraulic controlling cylinder, the piston rod of the steam and hydraulic pistons being the same. A pump is provided, connected with the hydraulic cylinder for reversing by hand.

The turning engine is a double, inverted, 3½ by 3½ by 4-inch engine, driving a worm shaft, which in turn drives a second worm, and which may be made at will to mesh with a worm wheel on either propelling shaft. The turning engine is made reversible by means of a change valve. A ratchet wrench is fitted for turning the engines by hand.

ENGINE DATA.

| | |
|---|---|
| Cylinders, number for each engine | 3 |
| H.P., diameter, inches | 17 |
| I.P., diameter, inches | 26½ |
| L.P., diameter, inches | 40 |
| Stroke of piston, inches | 24 |
| Valves, H.P. (one for each cylinder), diameter, inches | 9 |

| | |
|---|---|
| Valves, I.P. (two for each cylinder), diameter, inches | 9 |
| Valve stems, H.P. (1), diameter, lower ends, inches | 2 |
| through valve, inches | 1¼ |
| I.P. (2), diameter, lower ends, inches | 2 |
| through valve, inches | 1¼ |
| L.P. (1), diameter, lower ends, inches | 2¼ |
| through valve, inches | 1¾ |
| at balance piston, inches | 1½ |
| Piston rods, diameter, inches | 3¾ |
| length from piston to center of crosshead pin, inches | 42 5/8 |
| axial hole, inches | 1¾ |
| Connecting rods, center to center, inches | 48 |
| diameter, upper ends, inches | 3¾ |
| lower ends, inches | 4¼ |
| axial hole, inches | 2 |
| Main steam pipe (steel), diameter, inches | 5½ |
| exhaust pipe to condenser (copper), diameter, inches | 13½ |
| Crosshead pins, diameter, inches | 4¾ |
| length in bearing, inches | 8½ |
| Reversing gear, steam cylinder, diameter, inches | 8 |
| controlling cylinder, diameter, inches | 3½ |
| stroke, inches | 8 |
| Crank shafts, diameter, inches | 7½ |
| axial hole, diameter, inches | 4¾ |
| coupling discs, diameter, inches | 14½ |
| thickness, inches | 2 |
| bolts in one flange (6), taper, mean diameter, inches | 1¾ |
| Crank shaft journals, diameter, inches | 7½ |
| length, inches | 9 |
| axial hole, inches | 4½ |
| Crank webs, width, inches | 8¾ |
| thickness, inches | 4¾ |
| Thrust shaft, diameter, inches | 7½ |
| coupling disc, diameter, inches | 14½ |
| thickness, inches | 2 |
| axial hole, inches | 4½ |
| length, feet and inches | 9– 9 |
| collars, number, each shaft | 9 |
| diameter, inches | 11½ |
| distance between, inches | 2½ |
| thickness, inches | 1 |
| Surface, total, both engines, square inches | 940.5 |
| Propeller shaft, diameter inches | 7½ |
| axial hole, inches | 4½ |
| outboard length, feet and inches | 19– 3 |
| total length, feet and inches | 44– 7½ |

*Shafting and Bearings.*—The crank shafts are of forged steel, each being made in two parts, the forward section forming two cranks and the after section one. When the sections are bolted together the cranks are 120 degrees apart and their sequence is H.P., I.P., L.P., when in the ahead motions. The propeller shafts are fitted with a composition casing from forward of the stern-tube stuffing box to the propeller hub. The exposed portions of these casings are served with one layer of insulated copper wire $\frac{9}{16}$ inch in diameter, wound on tight and painted with three coats of the same composition as applied to the hull.

The thrust bearings are of the collar type. The pedestals and caps are cast iron, the side and end walls forming an oil trough, in which there is a copper cooling pipe. At each end there is a bearing five inches long lined with white metal. The collars are nine in number. An oil box is cast in the cap, from which the oil is led to the collars, and at each end is a divided stuffing box and gland to prevent the escape of the oil. There are four screw bolts, two at each end, for adjusting the bearing fore and aft.

*Main Condensers.*—There is a condenser for each main engine, made in three parts, of cast iron, and forming part of the engine framing. The tube sheets and tubes are of Muntz metal. Baffle, circulating and tube-supporting plates are fitted. The circulating water passes through the tubes. There are 913 tubes in each condenser, of $\frac{5}{8}$ inch outside diameter, and No. 18 B.W.G. thickness. The cooling surface of each condenser is 1,612 square feet.

*Main Air Pumps.*—For each main engine there is one vertical double-acting air pump worked from the L.P. crosshead. The cylinders are $16\frac{1}{2}$ inches in diameter and $8\frac{1}{2}$-inch stroke. The valves are made up of discs of manganese-bronze.

*Main Circulating Pumps.*—There are two centrifugal pumps with 8-inch inlet and outlet connections, arranged to draw from the sea, the bilge and the main drain, and discharge through condenser, or overboard direct. All suction valves are connected by a locking device so that only one valve can be operated at one time. A safety sluice valve is placed in each inboard and

outboard sea pipe. Each pump is driven by a two-cylinder simple engine, 5 by 5 by 5 inches.

*Auxiliary Condenser.*—There is one auxiliary condenser, located in the engine room. It has a combined air and circulating pump, with steam cylinder 6 inches in diameter; circulating pump, 10 inches in diameter; air pumps, 10 inches in diameter, with a stroke of 10 inches. Both condenser and pumps are of the Davidson pattern.

*Feed-Water Heaters.*—In the fire room are located two feed-water heaters, similar in construction to the condensers. They are placed in the feed lines between main feed pumps and boilers. The heating surface of the tubes is 133.7 square feet. The valves are arranged so that water may be passed direct to boilers or through heaters.

SCREW PROPELLERS.

The propellers as originally designed, at a pitch of seven feet nine inches, are true screws, rights and lefts, three-bladed, built up, with blades inclined aft 6 inches. The top tips of wheels turn inboard when in the ahead motion. The pitch is adjustable from 6 feet 9 inches to 8 feet 9 inches. The blades and hubs are of manganese-bronze tinned. When the blades are set to the desired pitch they are prevented from slipping by filling the spaces around the bolts in the palms of the blades with white metal.

For the trial the pitch was set to give an increasing pitch, as follows:

| | |
|---|---|
| On diameter of 40 inches, pitch, feet and inches | 8–2⅞ |
| 62 inches, pitch, feet and inches | 8–3¾ |
| 82 inches, pitch, feet and inches | 8–5 3/16 |
| Average, feet and inches | 8–3 11/16 |

| | |
|---|---|
| Number of blades | 3 |
| Diameter, feet and inches | 8– 6 |
| Pitch as set on trial, feet and inches | 8– 3 11/16 |
| Greatest width of blade, inches | 39½ |
| Helicoidal area of each screw, square feet | 25.95 |
| Projected area of each screw, square feet | 22.5 |
| Disc area of each screw, square feet | 56.74 |
| Ratio diameter to mean pitch | 1 to .9797 |
| Distance of center of hub above lowest point of keel, feet | 4.75 |
| Top of propeller immersed, feet | 3.5 |

BOILERS.

There are four boilers, of the Mosher type, in one watertight compartment, built by the contractor and designed for pressures of 250 pounds. The fire room runs fore-and-aft between engine-room passage way aft and the firemen's washroom forward. There is a passage way between the forward and after boilers on each side running to the side coal bunkers. The main feed pumps and the distilling plant are placed in the after part of the fire room. Two sections through the Mosher boilers are shown by Figs. 4 and 5.

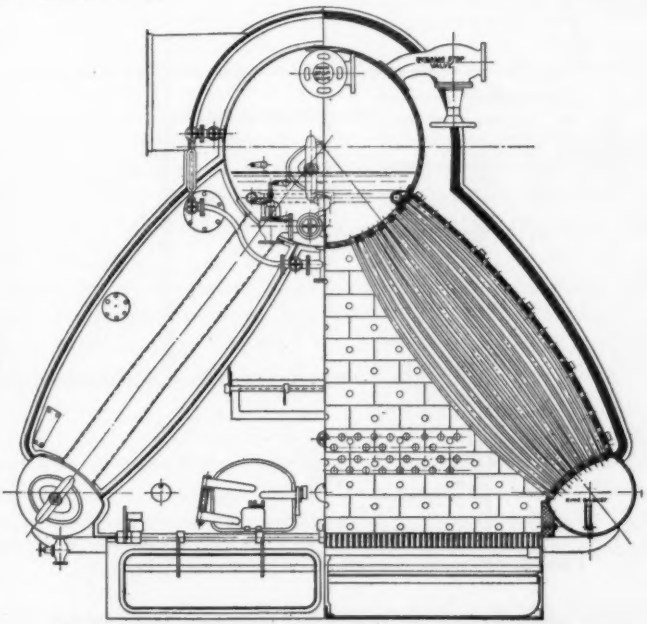


FIG. 4.—MOSHER BOILER, U. S. MONITOR "FLORIDA."

Each boiler consists of a water drum 42 inches inside diameter, 11 feet long, between bumped heads. The shell is $\frac{6}{10}$ inch thick, increased to 1 inch where tubes enter. This is connected to two water drums 19 inches in diameter, flattened where tubes enter,

by 1,392 tubes, $1\frac{1}{8}$ inches outside diameter, No. 11 B.W.G., and two down pipes $8\frac{1}{2}$ inches inside diameter, $\frac{1}{4}$ inch thick; 696 tubes and one down pipe running to each water drum. The tubes are very slightly bent, the radius of the outer ones being 11 feet 4 inches. There are twelve rows in each water drum. Each steam and water drum, with its heads, is in one piece, welded.

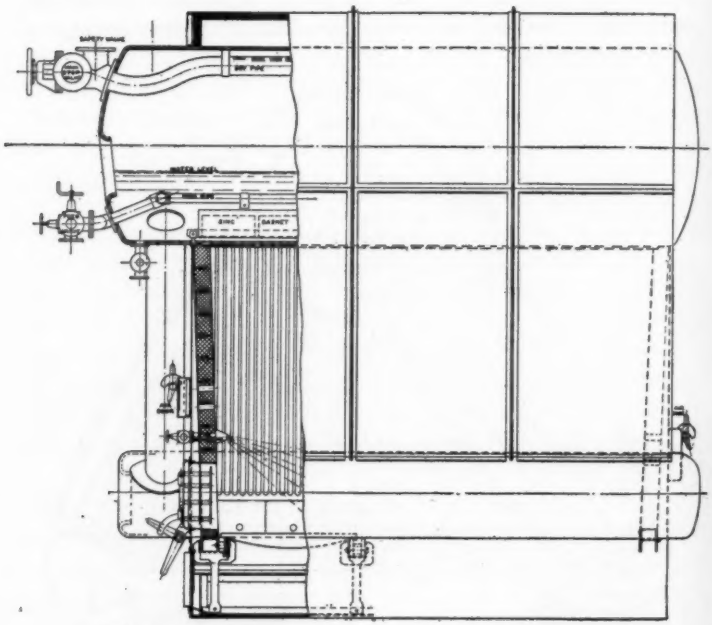


FIG. 5.—MOSHER BOILER, U. S. MONITOR "FLORIDA."

Each boiler has one furnace 8 feet wide by 7 feet 6 inches deep. Each is fitted with a spray just above the furnace door for extinguishing fire quickly in case of accident. Provision is made for admitting air above the grates. There is one smoke pipe for the four boilers with 31.5 square feet area, the top of the pipe being 73 feet above the grates. The pipe is cased, leaving an annular space of three inches.

| | |
|---|---|
| Heating surface, tubes and plate, one boiler, square feet | 2,400 |
| Grate surface, one boiler, square feet | 60 |
| Ratio grate to heating surface | 1 to 40 |
| Floor space occupied by one boiler (about 11 feet by 12 feet 3 inches), square feet | 135 |

WEIGHT OF ONE BOILER.

| | |
|---|---|
| Weight of one boiler complete, including internal and external fittings, viz: casings, main stop valve, safety valve, dynamo stop valve, gauge cocks, glass and mica water gauges, feed and filling valves, bottom and surface blow valves, drain valve, fire extinguisher, dry pipes, feed pipes, scum pan, zinc plates, and baskets, pounds | 28,514 |
| Weight, with details as above, including water to steaming level, pounds | 33,734 |
| Weight of water, 5 inches above highest heating surface, or 6 inches below center line of steam drum, pounds | 5,220 |

*Forced Draft.*—Two Sturtevant blowers, driven by two 5 by 5 by 4 inch single engines, furnish air for the forced draft in closed fire room. The diameter of the fan is 54 inches, area of induction nozzle 706.86 square inches, and eduction nozzle 1,488 square inches.

*Feed Pumps.*—There are two main feed pumps in fire room and two auxiliary feed pumps in engine room. Each main feed pump can draw from the reserve feed tanks, and from communicating pipes between feed tanks, and can deliver into the boilers or reserve tanks.

The auxiliary feed pumps draw from the communicating pipe between feed tanks, the sea, the drainage manifolds, the main drain and boilers, and discharge into the boilers, the fire main and flushing system, the distillers, circulating pipes and overboard. All of the above pumps are of the Blake pattern, 8 by 5 by 12 inches, vertical simplex.

*Fire and Bilge Pump.*—There is one Blake vertical simplex pump, 7 by 7 by 12, in the engine room which draws from the sea, the engine-room bilge, the main drain and drainage manifold, and discharges into the fire main, boiler, fire extinguisher and overboard.

*Water-Service Pump.*—There is one Blake vertical simplex 7 by 7 by 12 pump in engine room which draws from the sea only.

It delivers into the fire main, distiller circulating pipes and main-engine water service.

The auxiliary feed, fire and bilge, and water-service pumps have hose connections on both suction and discharge sides.

*Hotwell Pump.*—There are two Blake vertical simplex 6 by 5½ by 12 pumps in engine room which draw from the hotwell tanks, air pump channel ways, drain traps and reserve feed tanks, and discharge into the feed tanks and the reserve feed tanks. There is also a connection for taking in fresh water from side of ship for filling reserve feed tanks.

*Shaft Bilge Pumps.*—There are two shaft bilge pumps driven by eccentrics on main-engine shafts. They are of the plunger pattern; plunger, 5 inches diameter; stroke, 5 inches, and draw from the crank pits and discharge overboard.

*Feed Tanks.*—There is a combined feed and filter tank for each engine, each having a capacity of 330 gallons above dead water. There are connections for discharges from main air pumps, auxiliary air pumps, hotwell pump and drain traps, and communicating pipes between tanks. There are also eight reserve feed tanks (the double bottom compartments under fire room from frame No. 48 to frame No. 56 inclusive) of 40 tons capacity. Each can be pumped from separately.

*Hotwell Tanks.*—There are two hotwell tanks, each of 65 gallons capacity. There are connections for discharge from main air pump, auxiliary air pump, drain traps, communicating pipes and hotwell pump suction.

*Engineer's Workshop.*—The workshop is situated on the berth deck on the port side next to the turret and chain-locker enclosure. The tools, driven by a Greenfield 4 by 6 engine, consist of a 14-inch back-geared screw-cutting lathe, a column-shaping machine, a double-geared drill press, a 12-inch emery grinder. There is also a work bench with vise. All tools are driven by belting from the necessary line and counter shafts.

*Ash Hoist.*—There is a double cylinder 4½ by 4½ by 4½ Williamson's reversing ash-hoist engine for hoisting ashes through the fire-room ventilators. It will raise a filled ash bucket weighing 310 pounds in 5 seconds.

*Distilling Plant.*—The distilling plant is located in the after part of the fire room. It consists of two evaporators, two distillers, evaporator feed pump, and brine and distiller pumps, all of the Davidson pattern. The evaporators are so arranged that they may be operated in double effect, and each has a capacity of 2,500 gallons per 24 hours.

On a test each distiller showed a capacity of 2,518 gallons of fresh water per 24 hours at a temperature of 92 degrees. Temperature of circulating water, 41 degrees. Pressures: evaporator shell, 8 pounds; evaporator tube, 28 pounds. The evaporator feed pump is a vertical simplex pump, 5 by 3 by 6 inches, piped to feed both evaporators. The circulating water for distillers is supplied by the engine-room water service or the auxiliary feed pump. The brine and distiller pump is a combined fresh- and salt-water pump, $3\frac{1}{2}$ by $2\frac{1}{4}$ by $2\frac{1}{4}$ by 4 inches. The salt-water end can draw from the evaporator and discharge overboard. The fresh-water end can draw from the distiller reservoir tank and discharge into the feed tanks, reserve feed tanks and fresh-water tanks forward; in addition, the hand pump in the firemen's washroom can draw from the distiller reservoir tank.

*Steering Engine.*—In the steering-engine room there is a combined hand- and steam-steering engine of the Williamson Bros. Company's design, double cylinders, 8-inch diameter by 7-inch stroke. The engine is controlled from the conning tower and pilot house by wire ropes as far as the dynamo room, by shafting from that point to the wheel.

*Steam Windlass.*—A steam windlass of the Hyde Windlass Company's design is located forward on the main deck. The engine is reversible, double-cylinder, direct-acting, with cylinder 9-inch diameter and 9-inch stroke. It is fitted with two wild cats.

*Steam Winch.*—On the bridge deck, forward of the engine-room hatch, are located two double-cylinder horizontal winches of the Williamson Brothers design, cylinders 6-inch diameter and 6-inch stroke.

*Air Compressor for Long-Arm System.*—On the berth deck, forward of the dynamo room, on the port side, is the air compressor for operating the twenty-one watertight doors that belong to the

long-arm system. It is a vertical, triplex, single-acting, three-stage type, with cylinders of 2, $3\frac{3}{4}$ and $7\frac{3}{4}$ inches diameter, with 6-inch stroke, and is driven by a $7\frac{1}{2}$-H.P. electric motor, the bed plate containing both compressor and motor. It is fitted with intercooler and reheater.

*Heating System.*—Cast-iron radiators are used in the ward-room, staterooms and in captain's cabin. Coils are used in all other places. Branches from the main steam supply line of the heating system run to the bathtubs and showers. The captain's bath has an independent line from the auxiliary steam line.

## THE TRIAL.

The *Florida* left the contractor's dock, Elizabethport, New Jersey, for Bridgeport, Conn., Monday, March 16, 1903, at 7·15 A. M., arriving there the same day at 4 P. M.

The trial course, a distance of twelve knots, was buoyed off by the Navy Department, in Long Island Sound, nearly opposite Bridgeport, Conn.

The members of the Trial Board were Naval Officers, as follows: Captain C. J. Train, President; Captain C. R. Roelker, Commander W. C. Cowles and Naval Constructor J. J. Woodward.

The members of the Engineering Trial Board, Captain C. R. Roelker and Lieut.-Commanders John R. Edwards and W. M. Parks, of the U. S. Navy, assisted by the following Naval Officers: Lieutenant C. W. Dyson, Assistant Engineer R. E. Carney, Retired, Lieutenants U. T. Holmes, C. Wells, W. R. White and W. H. Reynolds, and Ensign J. Halligan, Jr.

In addition to these, Lieutenant Albert Moritz, U. S. Navy, the Naval Inspector of Machinery, and Assistant Naval Constructor Stuart Farrar Smith, Superintending Constructor at the works of the contractor, were present, on orders from the Navy Department, to furnish information and render assistance to the Trial Board. They were assisted by one draftsman (engineering), one special laborer (engineering), and one special mechanic (construction).

Commander J. C. Fremont, U. S. Navy, designated by the Navy

Department as the first Commander of the *Florida* when placed in commission, was present as a spectator.

Mr. Mason S. Chace, President of the Crescent Shipyard Company, was in immediate charge of the trial for the contractor. He was assisted by Mr. Eric Ewertz, Chief Constructor, and Mr. Charles C. Bowers, Superintending Engineer.

The trial crew was made up from the shops, as follows:

The engineer's force:
- One master mechanic,
- Two chief engineers,
- Four draftsmen.
- Eight engineers,
- Four oilers,
- Nine machinists,
- Nine firemen,
- Two boiler makers,
- Two boiler makers' helpers,
- One foreman pipe fitter,
- Four pipe fitters,
- Four pipe-fitters' helpers,
- Six coal passers,
- One foreman (hull machinery).

On deck:
- Captain W. T. Cox,
- One pilot,
- Doctor T. E. Nolan,
- One assistant superintendent,
- One drainage expert,
- One messenger,
- Eight riggers and deck hands,
- One caterer,
- Two cooks,
- Five messmen.

Electrical contractor's force:
- One superintendent,
- Two foremen,
- One bell-hanger,
- Three electricians.

There were four preliminary contractors' trials: December 7, 1902; February 21 and 27 and March 5, 1903; for the purpose of familiarizing the crew and getting the machinery in shape. An average speed of 12.75 knots was reached on the last contractor's run, over a measured course, between Fort Lafayette and Craven's Shoals, in New York Bay.

The official trial was set for March 18th, but the weather conditions prevented the buoys being placed until the afternoon of that date; so no run was made until the following day, March 19th. The Trial Board and all the assistants assembled on board the vessel off Bridgeport, Conn., about 10 A. M. Fog prevented the trial until 3 P. M., at which time the vessel was started over the course to locate the buoys and to warm up the engines.

During the warming-up run the engines were going at nearly maximum speed.

At 4·07 P. M. the vessel started on the trial, running over the course once, and, after a short turn, returning over the same course to the starting point, finishing at 6 h. 13 m. 44½ s. P. M.

The state of the sea was at all times smooth. The official run was in foggy weather, the last lap of the course being steered almost entirely by compass. On all the runs, almost half the distance between buoys (six miles) was run before the helmsman was able to pick up the buoy next ahead, and as the vessel was fitted with a special compass located in the pilot house, just over the conning tower, and, consequently, after being compensated with a very small directive force, the courses were not so accurately steered as would have been possible had the buoys been at all times visible. At full speed water came over the bow chock, and covered the main deck forward of the 12-inch guns.

Steam was maintained steadily with ease, and no endeavor to increase the pressure or revolutions was made during the trial. No change was made in the throttle valve or cut-off gear. Putting helm over while the vessel was making the turn between the two runs over the course reduced the speed of the port engine about 14 R.P.M. and that of the starboard engine about 11 R.P.M.

The fire room was kept closed during the trial. At no time did the pressure in the boilers exceed 212 pounds. The reflex water gauges, "Klinger Patent," were used on the boilers, and gave entire satisfaction. The fuel used was picked Pocahontas coal of good quality. A careful account of the coal used during the trial was kept, the coal being weighed in bags of 150 pounds each.

The following steam machinery was in operation during the trial, besides the main engines, circulating and feed pumps, viz:

One water-service pump,
One bilge pump,
Two dynamo engines,
Two fire-room blowers,
One steering engine.

## ENGINE-ROOM DATA.

Official Trial, U. S. Monitor *Florida*, March 19, 1903.

| Time. | | | Time interval. | Reading of counter. | Revolutions during interval. | Revolutions per minute. | Steam pressures. | | | | Vacuum. | Position of H.P. link, in tenths. | Temperatures. | | | | | | | | Revolutions per minute, or double strokes. | | | | Air pressure in inches of water. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | In boilers, above atmosphere. | In steam pipes at engine, ab. atm. | In 1st I.P. rec'r, absolute. | In L.P. rec'r, absolute.* | | | Engine room. | | Fire room. | | Injection. | Discharge. | Hotwell. | Feed | Circulating pump. | Water-service pump. | Feed pump. | Fire-room blowers. | |
| H. | M. | S. | | | | | | | | | | | Upper platform. | Working platform. | Above grating. | Working level. | | | | | | | | | |
| | | | | | | | | | | | *Port Engine.* | | | | | | | | | | | | | | |
| 4 | 07 | 00 | ... | 79,691 | ... | ... | 210 | 200 | 60 | 31 | 26 | .7 | ... | ... | ... | ... | 40 | 90 | 100 | 113 | 100 | 48 | 30 | ... | .35 |
| 4 | 22 | 00 | 15 | 82,604 | 2,913 | 194.2 | 201 | 190 | 60 | 32 | 24 | .7 | 96 | 100 | 135 | 125 | 40 | 92 | 98 | 97 | 90 | 48 | 30 | 412 | .35 |
| 4 | 37 | 00 | 15 | 85,580 | 2,976 | 198.4 | 206 | 200 | 60 | 27 | 27 | .7 | ... | ... | 134 | 131 | 40 | 100 | 96 | 114 | 85 | 48 | 26 | ... | .20 |
| 4 | 52 | 00 | 15 | 88,520 | 2,940 | 196 | 205 | 190 | 60 | 30 | 26 | .7 | ... | ... | 139 | 129 | 40 | 105 | 100 | 108 | 85 | 48 | 23 | ... | .50 |
| 5 | 06 | 34½ | 14m. 34½s. | 91,438 | 2,818 | 200 | 198 | 190 | 60 | 30 | 26 | .7 | 102 | 102 | 129 | 130 | 40 | 110 | 102 | 104 | 88 | 48 | 27 | 337 | .50 |
| 5 | 17 | 51 | ... | 93,590 | ... | ... | 203 | 190 | 60 | 29 | 26 | .7 | ... | ... | 128 | 129 | 40 | 105 | 100 | 120 | 85 | 48 | 26 | 470 | .30 |
| 5 | 32 | 51 | 15 | 96,580 | 2,990 | 199.3 | 192 | 190 | 60 | 29 | 26 | .7 | 110 | 102 | 129 | 126 | 40 | 100 | 100 | 126 | 85 | 48 | 25 | 482 | .35 |
| 5 | 47 | 51 | 15 | 99,480 | 2,900 | 193.3 | 212 | 190 | 60 | 27 | 26 | .7 | ... | ... | 125 | 116 | 40 | 100 | 100 | 176 | 85 | 48 | 25 | 547 | .60 |
| 6 | 02 | 51 | 15 | 102,450 | 2,970 | 198 | 205 | 190 | 60 | 27 | 26 | .7 | ... | ... | 128 | 125 | 40 | 102 | 100 | 222 | 85 | 48 | 26 | 503 | .60 |
| 6 | 13 | 44½ | 10m. 53½s. | 104,633 | 2,183 | 200 | 205 | 190 | 60 | 29 | 26 | .7 | 110 | 102 | 124 | 121 | 40 | 100 | 100 | 200 | 85 | 48 | 26 | 500 | .60 |
| | | | | | | | | | | | *Starboard Engine.* | | | | | | | | | | | | | | |
| 4 | 07 | 00 | ... | ... | ... | ... | 210 | 190 | 83 | 30 | 26 | ... | ... | ... | 138 | 125 | 40 | 102 | 103 | 112 | 230 | ... | 32 | 448 | .35 |
| 4 | 22 | 00 | 15 | 3,021 | 3,021 | 201.4 | 201 | 180 | 75 | 28 | 26.5 | ... | 96 | 100 | 134 | 131 | 40 | 93 | 92 | 110 | ... | ... | 28 | 382 | .35 |
| 4 | 37 | 00 | 15 | 6,040 | 3,019 | 201.2 | 206 | 220 | 65 | 26 | 26.8 | ... | ... | ... | 138 | 129 | 40 | 93 | 91 | 111 | 225 | ... | 32 | ... | .20 |
| 4 | 52 | 00 | 15 | 9,070 | 3,030 | 202 | 205 | 180 | 75 | 26.5 | 26.5 | ... | ... | ... | 129 | 130 | 40 | 93 | 94 | 110 | ... | ... | 36 | 450 | .50 |
| 5 | 06 | 34½ | 14m. 34½s. | 12,010 | 2,940 | 201.7 | 198 | 192 | 69 | 26.5 | 26.5 | ... | 102 | 102 | 128 | 129 | 40 | 91 | 93 | 112 | 220 | ... | 34 | 385 | .50 |
| 5 | 17 | 51 | ... | 14,230 | ... | ... | 203 | 200 | 68 | 27 | 26.5 | ... | ... | ... | 129 | 126 | 40 | 92 | 92 | 110 | ... | ... | 30 | 453 | .30 |
| 5 | 32 | 51 | 15 | 17,250 | 3,020 | 201.3 | 192 | 190 | 72 | 27 | 26.5 | ... | 110 | 102 | 125 | 116 | 40 | 90 | 92 | 111 | 225 | ... | 32 | 555 | .35 |
| 5 | 47 | 51 | 15 | 20,240 | 2,990 | 199.3 | 212 | 190 | 73 | 27 | 26.7 | ... | ... | ... | 128 | 125 | 40 | 91 | 93 | 112 | ... | ... | 36 | 545 | .60 |
| 6 | 02 | 51 | 15 | 23,260 | 3,020 | 201.3 | 205 | 180 | 73 | 27 | 26.5 | ... | ... | ... | 124 | 121 | 40 | 93 | 95 | 111 | 210 | ... | 48 | ... | .60 |
| 6 | 13 | 44½ | 10m. 53½s. | 25,500 | 2,240 | 205.7 | ... | 185 | 74 | 28 | 26.5 | ... | 110 | 102 | ... | ... | 40 | 92 | 95 | 110 | ... | ... | ... | ... | ... |

* NOTE.—The auxiliary exhaust turned into L.P. receivers.

The machinery worked well without heating, no water being used on the main engines except that provided for ordinary cruising.

FIRE-ROOM DATA.

| Time. | Boilers.—Steam pressure in pounds per square inch. | | | | Blowers.—Revolutions per minute. | | Air Pressure.—Inches of water. |
|---|---|---|---|---|---|---|---|
| | A | B | C | D* | No. 1. | No. 2. | Fire room. |
| *h. m.* | | | | | | | |
| 4·07 | 215 | 212 | 208 | 210 | 448 | 412 | ·35 |
| 4·22 | 207 | 206 | 203 | 201 | 382 | ... | ·35 |
| 4·37 | 217 | 215 | 208 | 206 | ... | ... | .20 |
| 4·52 | 207 | 208 | 206 | 205 | 450 | 337 | ·50 |
| 5·07 | 200 | 200 | 196 | 198 | 385 | 470 | ·50 |
| 5·22 | 205 | 207 | 202 | 203 | 453 | 482 | ·30 |
| 5·37 | 196 | 197 | 194 | 192 | 555 | 547 | ·35 |
| 5·52 | 216 | 216 | 212 | 212 | 545 | 503 | .60 |
| 6·07 | 210 | 208 | 206 | 205 | ... | 565 | .60 |

* This gauge was taken as correct.

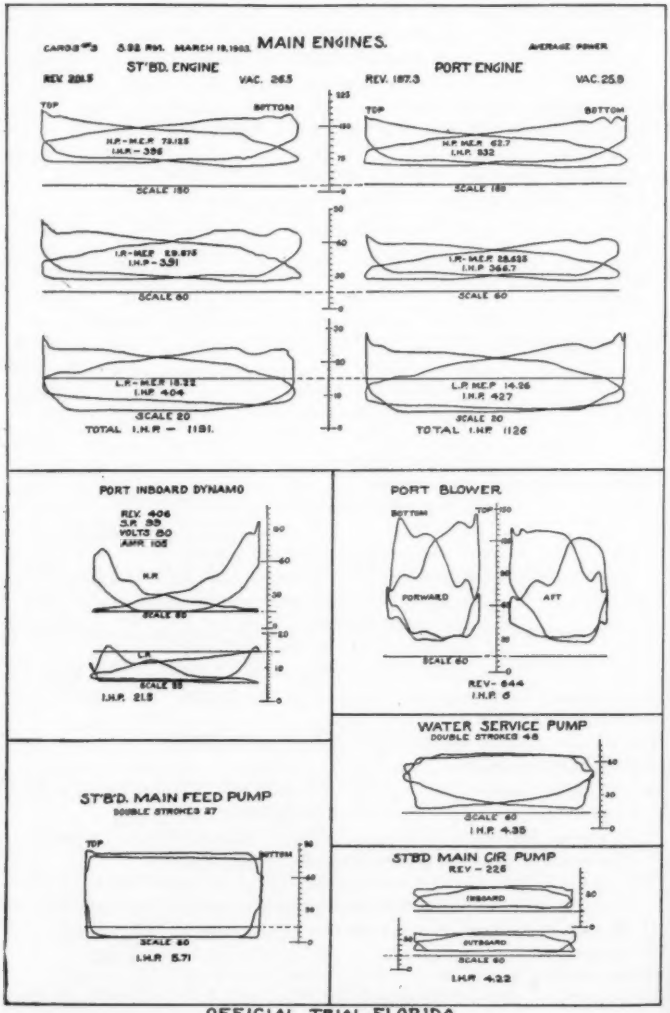
Attention is called to the high efficiency of the boilers.

After the return of the vessel to the works of the contractor a careful examination of the machinery was made by members of the Engineers' Trial Board, and found to be in excellent condition throughout.

PERFORMANCE—SYNOPSIS OF STEAM LOG.

| | *Starboard.* | *Port.* |
|---|---|---|
| Steam pressure at boilers, per gauge, pounds | 203.5 | |
| H.P. steam chest, per gauge, pounds | 190.7 | 192 |
| 1st receiver, absolute, pounds | 72.7 | 60 |
| 2d receiver, absolute, pounds | 27.3 | 30 |
| Vacuum in condensers, inches of mercury | 26.5 | 25.9 |
| Mean effective pressures in cylinders of main engines: | | |
| H.P., pounds per square inch | 73.125 | 62.7 |
| I.P., pounds per square inch | 29.875 | 28.625 |
| L.P., pounds per square inch | 13.22 | 14.26 |
| Mean pressure on L.P. piston, equivalent to aggregate M.E.P. on all pistons, pounds per square inch | 39 | 37.51 |
| of circulating pump (main), pounds per square inch | 18.75 | 18.75 |

| | | |
|---|---|---|
| Revolutions per minute, main engines | 201.42 | 197.3 |
| pump, circulating | 225 | 85 |
| pump-feed, double strokes | 33 | 26 |
| blower engines | 459 | 464 |
| Speed of ship in knots per hour | 12.4 | |
| Slip of propeller in per cent. of its own speed, based on mean pitch | 25.09 | 23.49 |
| Air pressure in fire room in inches of water | .417 | |
| Indicated horsepower, main engines: | | |
| H.P. | 396 | 332 |
| I.P | 391 | 367 |
| L.P. | 404 | 427 |
| Total | 1,191 | 1,126 |
| Total, both engines | 2,317 | |
| Indicated horsepower, circulating-pump engine | 4.22 | 1.6 |
| feed pumps | 5.71 | 7.05 |
| water-service pumps | ... | 4.35 |
| blower engines for forced draft in fire room | 12 | |
| dynamo engines | 43 | |
| Collective H.P. of all main engines | 2,317 | |
| main engines, circulating and feed pumps | 2,335.68 | |
| main and auxiliary engines during the trial | 2,395.03 | |
| all machinery during trial, per square foot of grate surface | 9.979 | |
| all machinery during the trial, per square foot of heating surface | .2495 | |
| Main engines, circulating and feed pumps, per square foot of grate surface | 9.73 | |
| Main engines, circulating and feed pumps, per square foot of heating surface | .2433 | |
| Coal, kind and quality: Hand-picked Pocahontas. | | |
| pounds per hour per I.H.P. collective, all machinery in operation | 1.986 | |
| pounds per hour per I.H.P. collective, main engines, circulating and feed pumps | 2.036 | |
| pounds per hour per square foot of grate surface | 19.82 | |
| pounds per hour per square foot of heating surface | .495 | |
| pounds per hour | 4,757 | |
| Cooling surface, square feet per I.H.P. | 1.34 | |
| Heating surface, square feet per I.H.P. | 4.08 | |




OFFICIAL TRIAL FLORIDA.
AVERAGE POWER CARDS.

FIG. 6.

RECAPITULATION OF WEIGHTS BY GROUPS.

| | |
|---|---|
| Group I.—Main engine cylinders, pounds | 33,349 |
| II.—Shafting, pounds | 19,389 |
| III.—Main-engine framing and bearings, pounds | 25,775 |
| IV.—Reciprocating part of main engines, pounds | 7,814 |
| V.—Main-engine valve gear, pounds | 7,751 |
| VI.—Main condensers, pounds | 27,657 |
| VII.—Main air and circulating pumps, pounds | 6,287 |
| VIII.—Propellers, pounds | 8,194 |
| IX.—Boilers, pounds | 72,617 |
| X.—Boiler fittings, pounds | 32,658 |
| XI.—Smoke pipes and uptakes, pounds | 38,085 |
| XII.—Steam and exhaust pipes and valves, pounds | 40,958 |
| XIII.—Suction and discharge pipes and valves, pounds | 29,547 |
| XIV.—Lagging and clothing, pounds | 15,165 |
| XV.—Flooring and gratings, pounds | 14,333 |
| XVI.—Auxiliaries, pounds | 22,420 |
| XVII.—Fittings and gear, pounds | 20,148 |
| XVIII.—Water, pounds | 31,368 |
| XIX.—Stores, tools and spare parts, pounds | 17,881 |
| XX.—Miscellaneous machinery, etc., pounds | 30,412 |
| Total pounds | 501,808 |

RECAPITULATION OF WEIGHTS BY CLASSES.

| | |
|---|---|
| Class I.—Propelling machinery, pounds | 422,147 |
| II.—Water in above machinery (boilers 5 inches above highest heating surface), 6 inches below center of steam drum, pounds | 31,368 |
| III.—Stores, tools, instruments and duplicate pieces | 17,881 |
| IV.—Miscellaneous machinery, under Bu. S.E. | 30,412 |
| Total weight.....pounds, 501,808 = tons, | $224\frac{448}{2240}$ |
| On board vessel during trial.....pounds, 495,115 = tons, | $221\frac{1971}{2240}$ |

The main point of difference between the monitors *Arkansas, Nevada, Wyoming* and *Florida,* lies in the type of boiler used. As all have had their official trials it is of great importance to note the comparative weight of machinery, particularly that of the boilers. The following data and remarks are therefore added to this article.

The table on next page shows in a very graphic manner the relation between boiler weights and the total weight allowed for machinery.

| | *Arkansas.* | *Nevada.* | *Wyoming.* | *Florida.* |
|---|---|---|---|---|
| Design of boiler..... | Thornycroft. | Niclausse. | B. & W. | Mosher. |
| Total weight of machinery allowed by contract, tons..... ..... | 240 | 240 | 240 | 240 |
| Authorized increase of weights, tons..... | 6.19 | 5.14 | 6.75 | 6.67 |
| Total weights permitted, tons ..... | 246.19 | 245.14 | 246.75 | 246.67 |
| Weight of boilers, fittings, smoke pipes and uptakes, tons..... | 84.84 | 111.74 | 89.43 | 64 |
| Actual weight of boilers and machinery as installed, tons..... | 254.24 | 279.37 | 263.3 | 224.02 |
| Excess of weights subject to financial penalty, tons..... | 8.05 | 34.23 | 16.55 | ... |
| Reserve of weight that contractor would have secured if Mosher boiler had been used, tons.. | 12.79 | 13.51 | 8.83 | 22.65 |

Since the only over-weights that are subject to financial penalty in the construction of a warship are those relating to machinery, it becomes a matter of importance to the builder what is the relative weight of different types of boiler installation, since practically no gain can be secured in the choice of propelling engines and auxiliaries. The above table clearly shows how close the weights for engines and auxiliaries independent of boilers approximate each other in the construction of the four monitors.

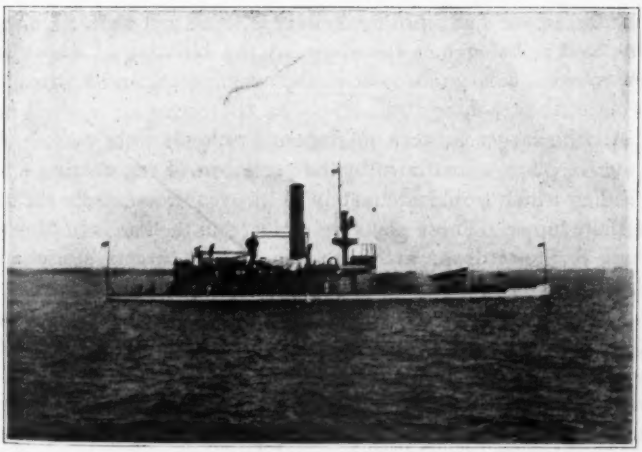
The weight of the Mosher boiler installed in the *Florida*, as compared with the other designs, is, therefore, respectively, two-thirds that of the Niclausse, three-fifths that of the Babcock & Wilcox, and three-fourths that of the Thornycroft.

The question of relative endurance and ability to withstand severe forcing for continuous periods in the various types of boilers installed in the four similar monitors has yet to be determined, and this can be done only by noting the actual results of continuous sea service.

The fact that the French Admiralty have officially declared against the use of small tubes in boilers of large ships of war, probably represents the views of the French experts as to the probable efficiency and endurance of the several installations.

In regard to the question of penalization for overweights of machinery, Rear Admiral Geo. W. Melville, Engineer-in-Chief, U. S. N., has asserted:

"It seems incomprehensible that a heavy financial penalty will be inflicted upon a shipbuilder who will provide for increased endurance and safety of the machinery by making some of the heavier parts heavier, while at the same time no financial penalty will be inflicted upon the same builder in case the weight of the luxuries should be greater than that originally allowed. In plain words, he is punished for making the ship more efficient and safe. Is it surprising, therefore, that the warship of one generation is the junk heap of the next, when practically everything is subordinated to making more attractive the appliances that are within sight, although such action causes a dangerously small factor of safety to be allowed for machinery and boilers? Massive and heavy furniture will be fitted in the ship, and yet essential portions of the machinery will be shaved to the danger point to save a few pounds in weight of some running part that is subjected to severe and continuous strain."



U. S. MONITOR "FLORIDA"
OFF BRIDGEPORT, CONN., FOR OFFICIAL TRIAL, MARCH 19, 1903.

# ENGINEERING BUILDING FOR THE UNIVERSITY OF PENNSYLVANIA.

By H. W. Spangler, Member; Professor of Dynamical Engineering, University of Pennsylvania.

The University of Pennsylvania has had under consideration for the past two years plans for increasing the facilities for undergraduate work in engineering.

At present the mechanical and electrical divisions of the work are done in the building containing the lighting station, where about 15,000 square feet of floor space are available. The civil engineering department has totally inadequate quarters in the college building.

The number of students taking these courses here, as at all the other engineering schools, has increased rapidly and the demand for more space and more equipment is to be met at this University, as it is being met elsewhere, by the building of additional laboratories, a large increase in their equipment and a strengthening of the teaching staff.

All the larger Eastern engineering schools were visited and tentative plans were drawn by the professors of engineering for a building which would adequately fill the requirements for the immediate future. These plans were placed in the hands of Messrs. Cope & Stewardson, architects, and after careful study and elaboration the plans shown herewith have been prepared.

The following description prepared by Professor Marburg and myself indicates the general feature of the building.

The building is to be 300 feet long and 160 feet deep, with a wing 50 feet wide on the west end extending 40 feet further to a small street in the rear. It is to be three stories high, with a basement covering about one-third of the area. By a suitable scheme of terracing, full advantage will be taken of the natural downward

slope of the ground toward the east to convert the basement at that end into practically a first story. The total floor space available in the building will be approximately 128,000 square feet, distributed as follows:

| | |
|---|---|
| Basement, square feet, . . . . | 15,600 |
| First floor, square feet, . . . . | 47,000 |
| Second floor, square feet, . . . . | 32,600 |
| Third floor, square feet, . . . . | 32,600 |
| Total, square feet, . . . . | 127,800 |

The construction will be fireproof throughout. The exterior will be of dark brick with sandstone trimmings, and the general architectural treatment and finish of the building will be in strict keeping with the high standards observed in the more recently constructed University buildings.

There will be two principal entrances leading to the main hallway, which will extend through the entire length of the building to staircases at both extremities. Two lightwells, about 80 by 50 feet, terminating in skylights over the first floor, will insure an abundance of light throughout the interior of the building.

The basement along the front will be occupied largely by commodious locker rooms and lavatories and by the necessary engine and machinery equipment for heating and ventilating purposes. A storage-battery room, to be used in connection with the electrical laboratories, will be located at the west end.

Along the eastern side of the building the basement will lie entirely above the ground level, becoming here virtually a first story, as previously stated. The space on this side will be assigned mainly to various laboratories. The surveying instruments will be kept in a room within easy access of a side exit, and this room will be utilized also as a geodetic laboratory. The hydraulic and physical testing laboratories will be located partly in this end of the basement. The remaining space will be occupied by a small laboratory for testing brick and by a shop and storage room.

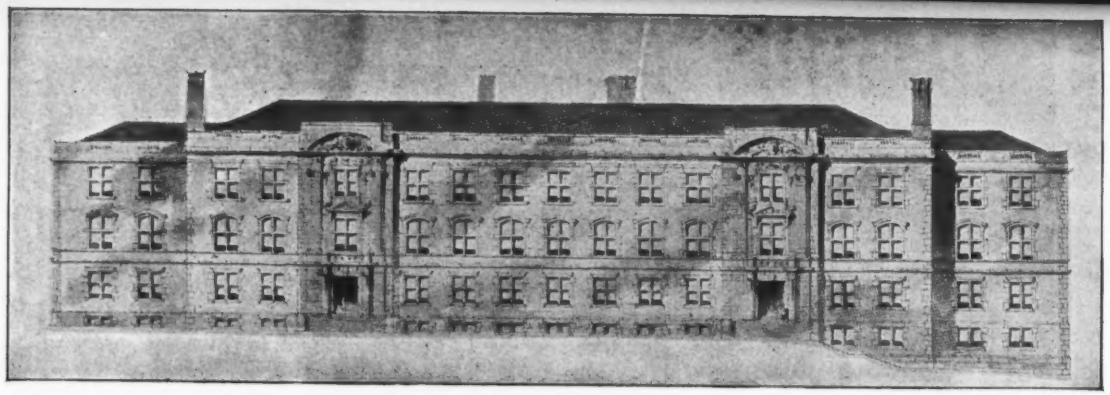
FIRST FLOOR.

On the first floor, immediately adjacent to the main entrances, will be the offices of the heads of the departments.

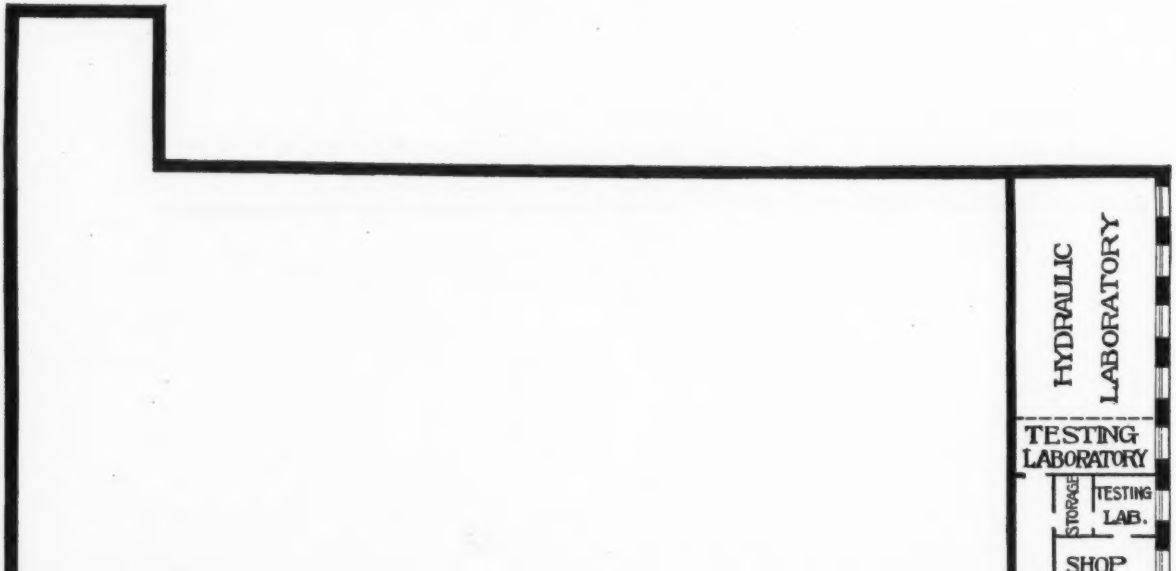
A spacious laboratory for the testing of cements, mortars and concrete will occupy the southeast corner. This room will contain testing machines of various types for tensile, compressive and bending tests, a briquette-making machine, immersion tanks, damp closets, etc., and a number of individual work tables, each completely equipped with an outfit of minor apparatus. It is intended to make special provision for investigating the effect of freezing on mortar and concrete by the installation of refrigerating apparatus.

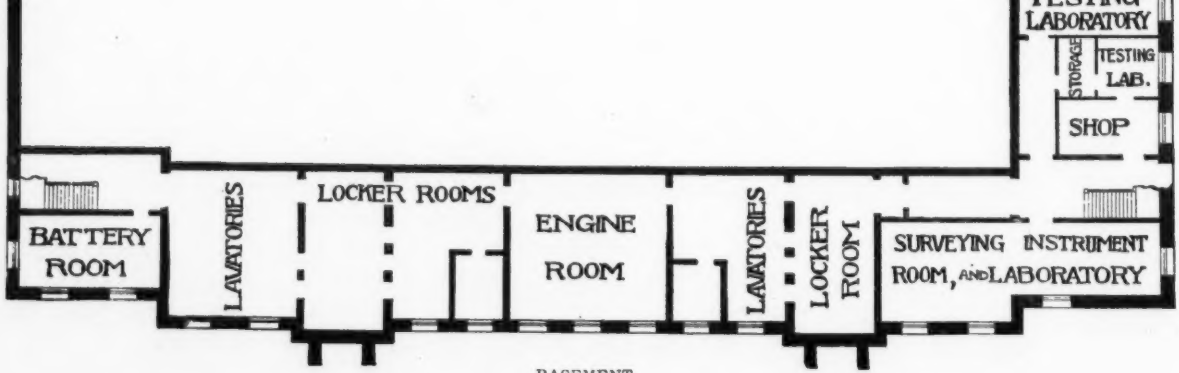
The eastern side of this floor will be otherwise occupied by the main physical testing and hydraulic laboratories, both extending partly into the basement, as previously stated. The former will contain universal testing machines of various types, ranging in capacity from 30,000 to 200,000 pounds; machines for torsion, bending and impact tests, besides a complete outfit of extensometers, deflectometers, cathetometers, micrometers, etc.

The hydraulic laboratory will contain a pressure tank, 5½ feet in diameter and 37 feet high, having a total capacity of 5,800 gallons, for experiments on the discharge through orifices and tubes, and two calibrated weir tanks, 5 by 5.5 feet in cross-section and 34 feet long. These tanks will be provided with partially removable ends to permit also of observations of flow over submerged weirs and dams. The weighing tanks, having each a capacity of 1,350 gallons, will be mounted on scales at the discharge ends of the weir tanks, and will themselves empty by quick-discharge valves into the main supply tank directly underneath. This tank will have a capacity of 23,000 gallons and will be connected with the city water mains and, by overflow and drain pipes, with the sewer. It will be below the basement floor level, so that it may receive the discharge from any piece of apparatus either on the basement or first-floor level. An 8-inch tubular well, 100 feet deep, will pass through the floor of this tank and will be utilized in connection with experiments on the efficiency of various forms of deep-well pumps and air lifts. The

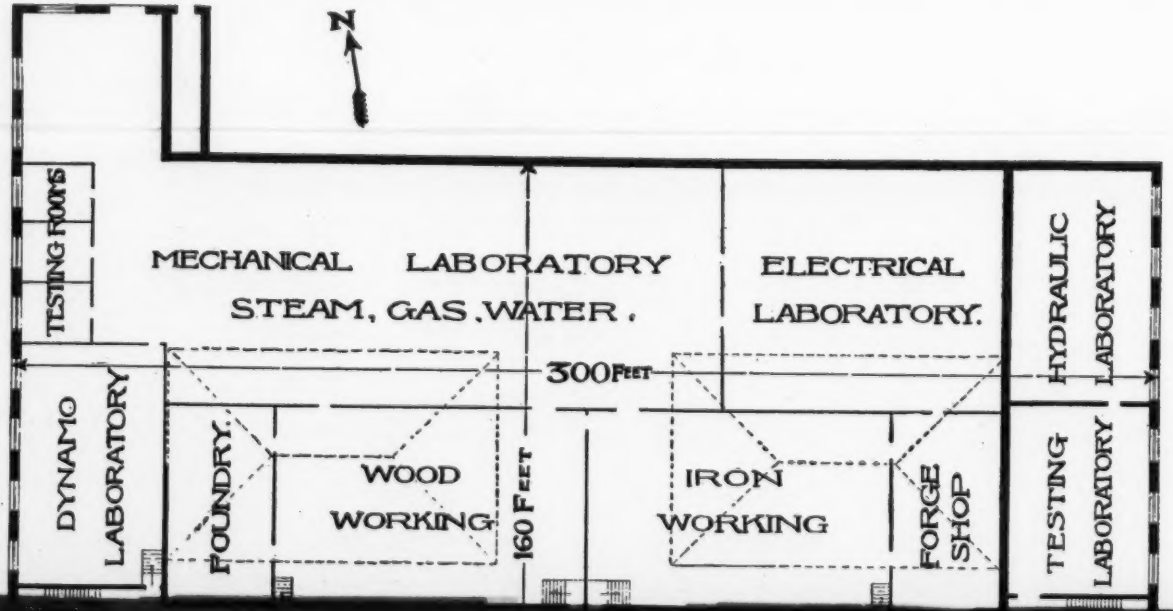


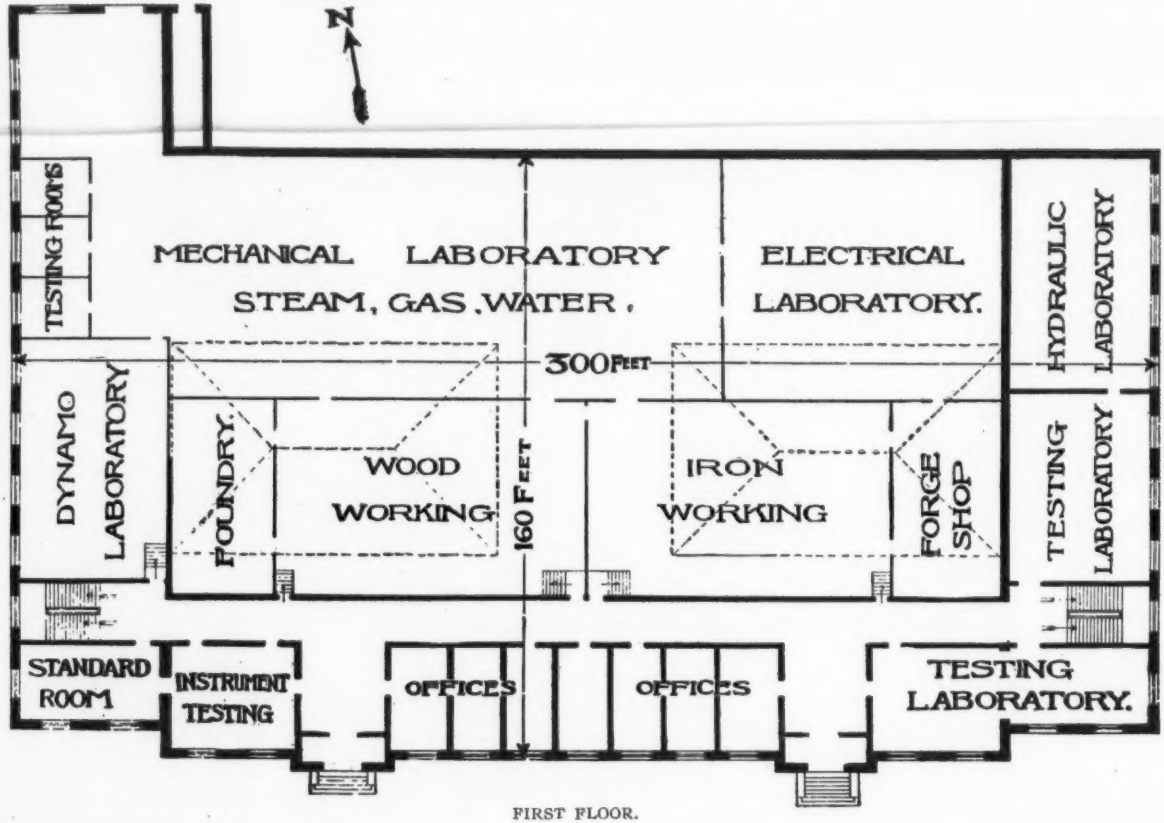
THE NEW ENGINEERING BUILDING.




TESTING LABORATORY
STORAGE
TESTING LAB.
SHOP
BATTERY ROOM
LAVATORIES
LOCKER ROOMS
ENGINE ROOM
LAVATORIES
LOCKER ROOM
SURVEYING INSTRUMENT ROOM, AND LABORATORY

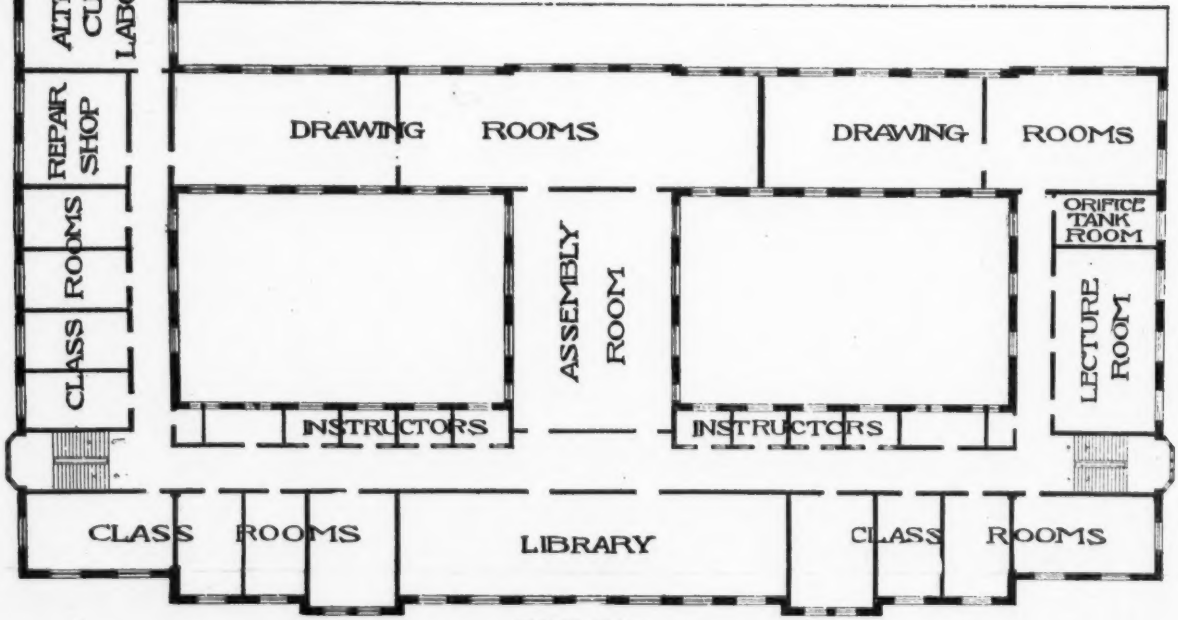
BASEMENT.


N
TESTING ROOMS
MECHANICAL LABORATORY
STEAM, GAS, WATER.
ELECTRICAL LABORATORY.
HYDRAULIC LABORATORY
300 Feet
DYNAMO LABORATORY
FOUNDRY.
WOOD WORKING
160 Feet
IRON WORKING
FORGE SHOP
TESTING LABORATORY


N
TESTING ROOMS
MECHANICAL LABORATORY
STEAM, GAS. WATER.
ELECTRICAL
LABORATORY.
HYDRAULIC LABORATORY
300 FEET
DYNAMO LABORATORY
FOUNDRY.
WOOD WORKING
160 FEET
IRON WORKING
FORGE SHOP
TESTING LABORATORY
STANDARD ROOM
INSTRUMENT TESTING
OFFICES
OFFICES
TESTING LABORATORY.

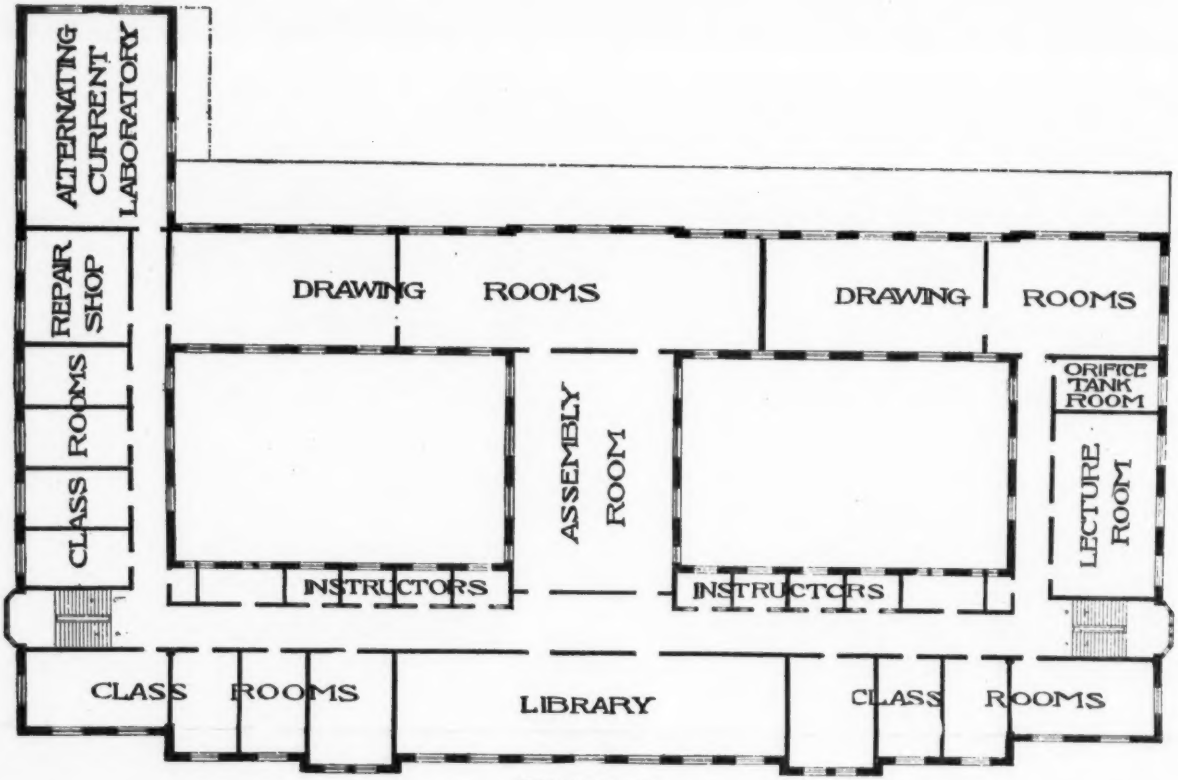
FIRST FLOOR.

ALTERNATING CURRENT LABORATORY
DRAWING
ROOMS
DRAWING
ROOMS



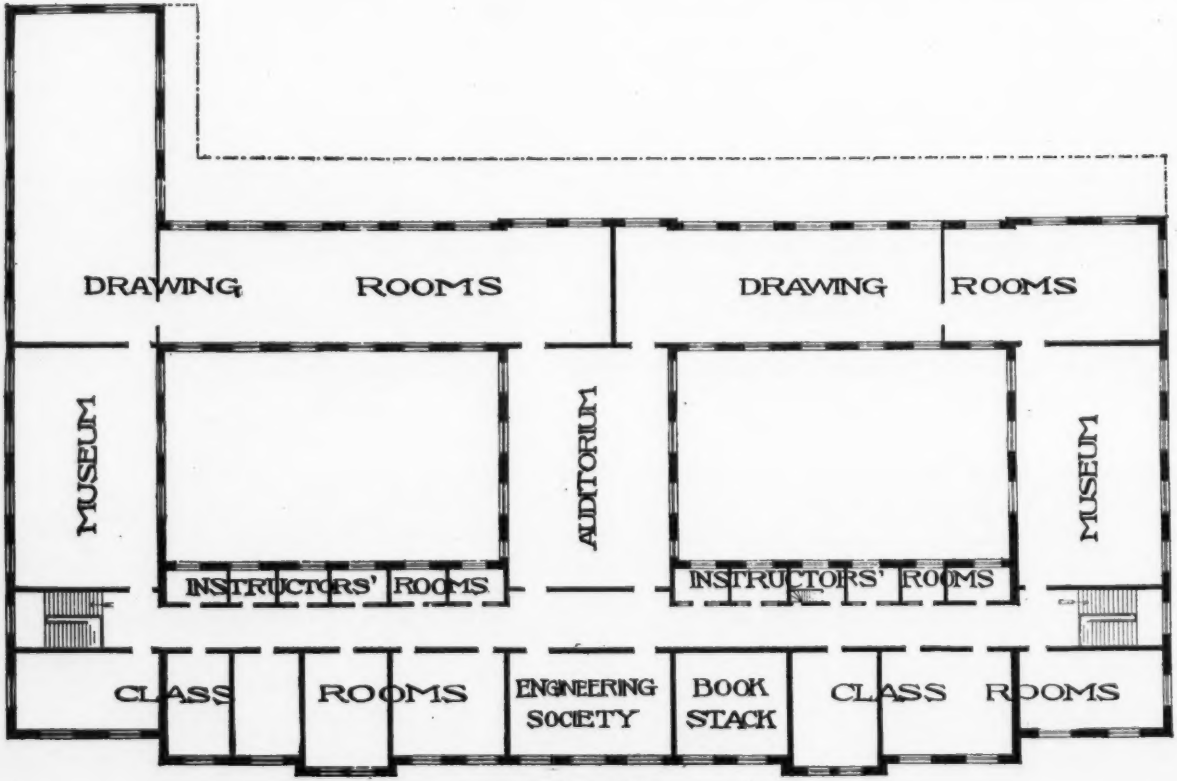

SECOND FLOOR.

FIRST FLOOR.




SECOND FLOOR.

SECOND FLOOR.




THIRD FLOOR.

pumping plant will consist of three units independently driven by variable-speed motors, so that they may be operated either separately or combined and at various speeds, thus ensuring a wide range in the rate of supply.

Various pipe circuits will be provided and connected with a 12-inch standpipe, extending from the basement to a height of about 65 feet, or somewhat above the main roof. From numerous connections along these pipe lines water will be supplied to various forms of minor apparatus.

On the west end, opening out of the main hall, will be an instrument-testing room for the calibration of indicators, thermometers, calorimetric work with fuels, etc., and beyond that an electrical-standard room for the comparison and correction of electrical testing apparatus of every variety. The remaining mechanical and electrical laboratories will be situated on a floor four feet below the entrance hall.

The central space under the skylights, about 200 by 50 feet, will be utilized entirely for workshops. In the western end will be a foundry equipped with a small cupola, brass furnaces and light crane for handling flasks and ladles. A moderate-sized sand floor in the center, and a small core oven and benches around the outside, will complete the equipment.

The wood-working and pattern shop will extend to the middle of the building and will be divided into two parts, the one intended for beginners and the other for students engaged on pattern work.

The tool room supplying the wood and iron shops will be placed directly at the center of the building. To the east of this will be an iron-working shop divided into two departments—one for beginners, the other for more advanced students.

The various forms of lathes, planers, drill presses, etc., required in a modern shop, will be installed, besides a number of electrically-driven tools.

The eastern end of the shop space will be devoted to the forge shop, with accommodations for fifteen men working simultaneously. Collectively, the shops will accommodate about ninety men working at the same time.

To the west and north of the shops will be the mechanical

laboratory and a part of the electrical laboratories. At the western entrance will be a dynamo and motor room, in which direct-current work will be carried on. Provision for high-voltage and railway work will be made in the adjacent laboratory.

In the mechanical laboratory steam and gas engines will be installed, each installation being complete with its apparatus for doing the special kind of testing for which it is to be used. Certain engines will be used for valve settings, others for determining mechanical efficiency, and others for determining the entire heat efficiency of the installation. A condensing apparatus and a small cooling tower for the steam engines and a moderate-sized suction producer in connection with the gas engines will make a complete working installation. A high-pressure water service with accumulators and belted and steam-driven air compressors will make it possible to carry on any experiments with hydraulic and compressed-air transmission. A boiler of 100 horsepower to supply saturated or superheated steam for experimental purposes will be installed near a small erecting floor, on which any kind of machine may be mounted and quickly connected up. Special testing rooms will be provided for refrigerating work, for experiments on heat transmission through pipes and radiators, and for experimental work on fans. Apparatus will be installed for measuring power transmitted in various ways and for testing the materials used by the mechanical engineer. A large water-supply tank will be located above the third floor, and cisterns beneath the first floor will receive the discharge from the various machines. A number of water wheels now in the possession of the department, steel flumes for handling the water and weirs and meters for measuring it, will afford facilities for laboratory work in this line.

Adjacent to the mechanical laboratory will be the electrical laboratory, in which all measurements to be made away from the machines will be carried on.

SECOND FLOOR.

A reference library and reading room will occupy the central space on the front of the building. The library and stack at one

end have been planned to hold about 20,000 volumes. The library is flanked on either side by a series of recitation and lecture rooms, which are continued along both ends of this floor.

Between the lightwells at the center of the building will be a students' assembly room with about 2,500 square feet of floor space. Instructors' rooms will be provided along the south side of the lightwells.

The rear portion of this floor for nearly the entire length of the building will be assigned to drawing rooms. A separate room will be alloted to each class and an individual desk to each student, so that he may have free access to the same at all hours.

The extension on the west side will be utilized for an alternating-current laboratory, with facilities for two and three-phase work and photometric work. An instrument repair shop will be adjacent to this laboratory.

THIRD FLOOR.

A room intended for the use of the engineering societies, a general supply store and the library stack will occupy the middle of the front of the building; the space along the front being otherwise assigned to class rooms and to instructors' rooms along the south of the lightwells.

In the east and west wings spacious rooms will be set aside for engineering museums. The rear of this floor will be devoted entirely to drawing rooms which, like the drawing rooms on the second floor, will have the full advantage of north light through windows of ample dimensions.

The building will be heated by direct steam, the ventilation being provided for by electrically-driven fans, supplying tempered air to the various rooms. The lighting throughout will be by electricity.

It is expected that the building will be completed and made ready for occupancy by the fall of 1904. It may be confidently affirmed that the University will then be in possession of unexcelled facilities for purposes of engineering instruction.

# OFFICIAL TRIALS OF THE SUBMARINE BOATS *GRAMPUS* AND *PIKE*.

By Leo Morgan, Member.

During the month of April, 1903, the *Grampus* and the *Pike*, two of the six submarine boats authorized by the Congress in June, 1900, were given their preliminary official trials in San Francisco Bay. These trials extended over a period of 11 days, and were conducted by a Board of naval officers.

## BRIEF DESCRIPTION OF THE SUBMARINES.

The *Grampus* and the *Pike* are sister boats of the *Adder* and the *Moccasin*, whose official trials took place last November in Peconic Bay, Long Island Sound. For surface propulsion power is transmitted from a 4-cylinder Otto gasoline engine of 160 horsepower, through suitable gearing, to the propeller. Each cylinder can be worked independently of the others.

For submerged work there has been installed a 70-horsepower electric motor, receiving current from storage batteries having a combined capacity of 1,840 ampère hours at the normal rate of discharge. Through suitable clutches and gearing, motion is transmitted to the propellers.

Owing to the gasoline engines not being reversible, the electric motor only is used when coming alongside or leaving a landing.

For submarine propulsion the electric motor has to be used, as it is impracticable to operate the gasoline engine under this condition.

Submergence is secured by means of the two diving rudders and by filling the trimming and the ballast tanks.

The proper trim for submergence is obtained by the admission of water to the forward and to the after trimming tanks as well as to the main ballast tank. When the proper quantity of water has been admitted to the necessary tanks the boat is very

U. S. Submarine Boat "Grampus" Returning to Dock from 10-Mile Speed Trial.

Operating under electric motor and at awash floatation. Speed about 6½ knots. San Francisco, April 8, 1903.

sensitive to the action of the diving rudders, but a speed of at least 6 knots is required to control the vertical movement of the craft.

Emergence is secured by operating the diving rudders and by the expulsion of the water ballast. The expulsion of water from the ballast tanks is accomplished by admitting air from the storage flasks, reducing valves being used to maintain the necessary pressure.

The diving and the steering rudders are operated by hand, being fitted with suitable gearing for reliable and prompt operation.

PROPELLER.

The propellers used on these boats are single, left-handed, three-bladed screws, and are of the same design as those used on the *Adder* and the *Moccasin*.

The principal dimensions of the propellers are as follows:

| | |
|---|---|
| Diameter, feet | 6 |
| Diameter of boss, feet and inches | 2- 8 |
| Mean pitch, feet and inches | 3-11 |
| Helicoidal area (three blades), square feet | 7.47 |
| Projected area (three blades), square feet | 7.194 |
| Disc area (three blades), square feet | 28.274 |

Further details of this propeller are shown on page 42 of this volume.

STORAGE BATTERY AND MOTOR.

The storage battery consists of 60 cells of 1,840 ampère hours capacity. The cells are fitted in a similar manner to those on the *Adder* and the *Moccasin;* and, as is the case in those boats, no provision has been made for preventing the overflow of the acid when the boat pitches or rolls.

Nominal H.P. of motor, 70; number of poles, 4; nominal speed, 800 R.P.M. Motor is shunt wound, full-load current, 500 ampères at 115 volts.

VENTILATION.

For this purpose there is supplied one $\frac{1}{6}$-H.P. Diehl motor and Root blower, near the engine. There is a $\frac{1}{12}$-H.P. Diehl fan motor in the stern of boat, and for ventilating the battery

tanks there is a ½-H.P. General Electric Co. motor in the space between tanks below the deck. Air is supplied through the conning tower and the torpedo hatches, and from one 4-inch ventilator. The air is exhausted from the top of the forward end of engine room by the ⅙-H.P. motor and blower, through a 2½-inch pipe, which is much too small to do the work required.

During the 12-hour endurance trial, after about five hours' running, the air in the engine room was noticeably bad, and became gradually very much worse. In rough weather or at sea, the torpedo hatch and the conning tower will be closed, leaving the 4-inch ventilator as the only means of fresh-air supply. With the gasoline engine in use for surface and for awash runs, the ventilation system as now installed is inadequate to ventilate the boat properly, a fact which was clearly emphasized by the placing of four additional electric fans in position to blow the air up the open hatch. This temporary installation of blowers was without appreciable benefit, showing the difficulty of ventilating the boat.

Any neglect or failure to keep the cylinders properly oiled will also enhance this trouble, as was shown when, after about nine hours' running, the air became so bad abaft the engine-room partial bulkhead, that it would not have been possible for a single crew to have kept the boat running for any great length of time.

### CONNING.

In the surface and the awash runs these boats were conned in the manner usual to steam vessels, except that in addition to the captain at the wheel that controls the vertical rudders, there was a helmsman at the wheel for the horizontal (diving) rudders. The latter is below deck and out of sight of the former, who is absolutely dependent on the skill of the diving helmsman to keep the trim constant, as there is no tell-tale in the conning tower to inform the captain of the position of the diving rudders. It is impossible for the latter to manipulate both the diving and the steering rudders. In getting up to full speed in either the light or the awash conditions the trim of the submarine is varied by command of the captain to suit the conditions of sea, some-

times the diving rudders being shifted gradually as much as 4 degrees.

In the lightest condition the reserve buoyancy of the submarine is quite small, and while under the gasoline engine the conning-tower hatch cover must be left off to supply air for the engine; should the man at the diving wheel make a mistake in handling his helm, or should he lose his nerve, the boat might easily—in fact, too easily—take a downward plunge, which would certainly endanger most of the crew, the top of the conning tower being about four feet above the water line.

While making the submerged runs the boats were conned by compass, their positions during these runs were shown by a small flag carried at the head of a temporary mast fitted in the bow.

### WEATHER.

Fine weather and smooth water were experienced during the several days of trial, excepting on April 9th, which happened to be the day selected for making the 3-hour submerged run. On that date a fresh to strong westerly wind prevailed, with a cloudy sky and a moderate sea. But the only appreciable effect on the *Pike* was that, by reason of the sloppy water and the overcast sky, it was quite difficult to see anything through the conning-tower lenses when the boat rose for observation.

### NUMBER AND DESCRIPTION OF CREW.

| | |
|---|---|
| 1 Helmsman in command, | 1 Gunner, |
| 1 Helmsman at diving wheel, | 1 Machinist and oiler, |
| 1 Engineer, | 1 Man at air and water valves. |
| 1 Electrician, | — |

Total, 7.

### TOWING.

No attempt was made to determine the speed at which these boats can be towed. According to the Holland Co.'s representative, however, the boats tow very well if the towing eyes are located near the axis and a helmsman is on board to steer. Since many advocates of the submarine contend that such boats should be towed to a point near their field of operation, the highest speed at which such towing could be done should be ascertained.

### TRIAL COURSE.

The trial course, laid out by the U. S. Coast and Geodetic Survey, was in San Francisco Bay, between the Union Iron Works and Hunter's Point and was two miles in length. The standardization runs were made over the first mile, and the half mile of this course, and the torpedo trials over the full course.

### SCOPE OF TRIAL.

In addition to the observers who took data within the submarines, the standardization runs were witnessed from the tender by observers who took notes of all that transpired. The endurance runs were also observed and reported on by those members of the Board who were on the tender which always followed in the wake of the submarine under trial.

According to the terms of the contract, the following trial runs were to be made:

(1) *Light.*—Standardization surface runs in light condition, using gasoline engine only; contract speed, 8 knots.

(2) *Awash.*—Standardization runs in awash condition, the gasoline engine only being used; contract speed, 7 knots.

Note.—In the "awash" condition, the boats are trimmed for diving, except that the main ballast tank is empty, the conning-tower hatch cover is kept open and the after ventilator is shipped and open for purposes of ventilation, but with everything else in readiness for commencing submerged work. Under these conditions the boat is supposed to be able to dive at short notice.

(3) *Submerged.*—Standardization runs in completely submerged condition; contract speed, 7 knots.

Note.—In the submerged condition only the electric motor is in operation. The boat, having been put in trim for diving, is given a reserve buoyancy of about 300 pounds in order to provide against the possible contingency of the diving gear failing to work.

(4) *Light.*—Trial for surface speed in light condition, under gasoline engine only, consisting in making a run in free route of not less than 10 nautical miles, at a speed of not less than 8 knots.

(5) *Awash.*—Trial for surface speed in awash condition, using gasoline engine only.

(6) *Torpedo-firing Trial.*—Consisting of a submerged run of 2 knots at an average speed of not less than 7 knots, and the firing of a torpedo at a target at the end of the run.

(7) *Submerged Endurance.*—A 3-hour completely-submerged endurance trial, under the electric motor only, at a minimum speed of 7 knots.

(8) *Twelve-hour Endurance.*—A 12-hour endurance of the gasoline engine with the vessel in light condition.

STANDARDIZATION RUNS.

There were two courses over which the standardization runs were made. In the surface and the awash runs, where the gasoline engine alone was used, the standardizing course was one mile in length. For the submerged runs, where the electric

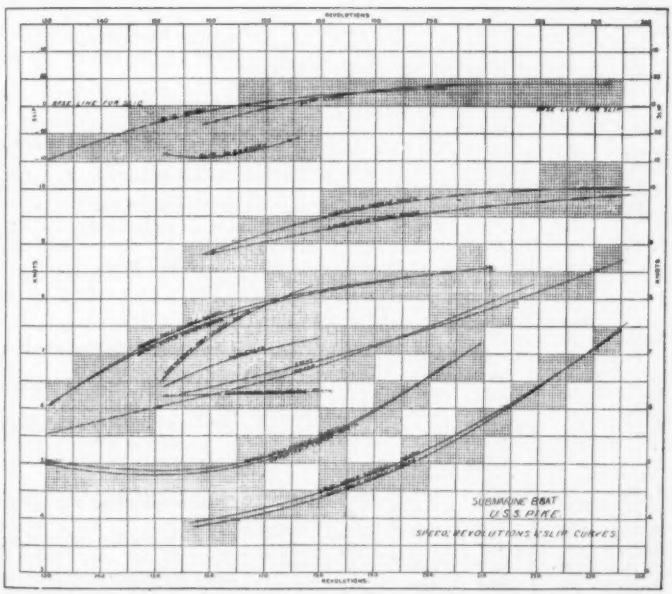



FIG. 1.—U. S. SUBMARINE BOAT "PIKE."—STANDARDIZATION RUNS.

motor only was used, the runs were made over the last half mile of the mile course.

The standardization trials were in three sets for each vessel—1st, in light condition; 2d, awash, and 3d, submerged—and are each shown in accompanying Tables Nos. I, II and III.

**TABLE I.**—STANDARDIZING TRIALS, LIGHT CONDITION.

| Run. | Elapsed time for counter readings. | Total revolutions. | R. P. M. | Elapsed time over course. | Speed, knots per hour. | Remarks. |
|---|---|---|---|---|---|---|
| | | | **"PIKE."**—APRIL 1, 1903. | | | |
| | | | OVER FULL-MILE COURSE. | | | |
| | *Min.* | | | *Sec.* | | |
| 1, S. | 8 | 1,284 | 160.50 | 408.9 | 8.82 | Used 2 cylinders of engine. |
| 2, N. | 4 | 631.5 | 157.87 | 915.6 | 3.94 | |
| 3, S. | 4 | 798 | 199.50 | 377.8 | 9.55 | Used 3 cylinders of engine. |
| 4, N. | 6 | 1,197.5 | 199.58 | 690.3 | 5.25 | |
| 5, S. | ... | ... | ... | ... | ... | Igniter insulator broke. |
| 6, N. | 6 | 1,377.5 | 229.58 | 512.2 | 7.05 | Used 4 cylinders of engine. |
| 7, S. | 4 | 921.5 | 230.37 | 365.1 | 9.89 | |
| | | | OVER SOUTHERN HALF-MILE COURSE. | | | |
| 1, S. | 8 | 1,284 | 160.50 | 202 | 8.87 | Used 2 cylinders of engine. |
| 2, N. | 4 | 631.5 | 157.87 | 466.4 | 3.85 | |
| 3, S. | 4 | 798 | 199.50 | 182.4 | 9.82 | Used 3 cylinders of engine. |
| 4, N. | 6 | 1,197.5 | 199.58 | 350 | 5.12 | |
| 5, S. | ... | ... | ... | ... | ... | Igniter insulator broke. |
| 6, N. | 6 | 1,377.5 | 229.58 | 257 | 7.07 | Used 4 cylinders of engine. |
| 7, S. | 4 | 921.5 | 230.37 | 181 | 10.04 | Last double run over northern half mile. |
| | | | **"GRAMPUS."**—APRIL 4, 1903. | | | |
| | | | OVER FULL-MILE COURSE. | | | |
| 1, S. | 6 | 966 | 161 | 401 | 9 | Used 2 cylinders of engine. |
| 2, N. | 7 | 1,108 | 158.27 | 967.9 | 3.63 | |
| 3, S. | 5 | 995 | 199 | 375.7 | 9.60 | Used 3 cylinders of engine. |
| 4, N. | 6 | 1,177 | 196.17 | 753.7 | 4.79 | |
| 5, S. | 4 | 912 | 228 | 341.5 | 10.57 | Used 4 cylinders of engine. |
| 6, N. | 6 | 1,362 | 227 | 930 | 6.33 | |
| | | | OVER SOUTHERN HALF-MILE COURSE. | | | |
| 1, S. | 6 | 966 | 161 | 202 | 8.87 | Used 2 cylinders of engine. |
| 2, N. | 7 | 1,108 | 158.27 | 491 | 3.65 | |
| 3, S. | 5 | 995 | 199 | 185.7 | 9.63 | Used 3 cylinders of engine. |
| 4, N. | 6 | 1,177 | 196.17 | 379 | 4.73 | |
| 5, S. | 4 | 912 | 228 | 169.5 | 10.57 | Used 4 cylinders of engine. |
| 6, N. | 6 | 1,362 | 227 | 283 | 6.33 | |

**TABLE II.**—STANDARDIZING TRIALS, AWASH CONDITION.

| Run. | Elapsed time for counter readings. | Total revolutions. | R. P. M. | Elapsed time over course. | Speed, knots per hour. | Remarks. |
|---|---|---|---|---|---|---|
| | | | **"PIKE."**—APRIL 2, 1903. | | | |
| | | | OVER FULL-MILE COURSE. | | | |
| | *Min.* | | | *Sec.* | | |
| 1, S. | 4 | 656 | 164 | 468.4 | 7.70 | Used 2 cylinders of engine. |
| 2, N. | 8 | 1,276 | 159.5 | 736 | 4.90 | |
| 3, S. | 4 | 802 | 200.5 | 426.9 | 8.45 | Used 3 cylinders of engine. |
| 4, N. | 7 | 1,385 | 197.9 | 561 | 6.43 | |
| 5, S. | 7 | 918 | 131.1 | 591.5 | 6.10 | Used 2 cylinders of engine, with late ignition in one. |
| 6, N. | 9 | 1,170 | 130 | 715.6 | 5.04 | |
| | | | OVER SOUTHERN HALF-MILE COURSE. | | | |
| 1, S. | 4 | 656 | 164 | 230.4 | 7.77 | Used 2 cylinders of engine. |
| 2, N. | 8 | 1,276 | 159.5 | 371.5 | 4.83 | |
| 3, S. | 4 | 802 | 200.5 | 211.9 | 8.45 | Used 3 cylinders of engine. |
| 4, N. | 7 | 1,385 | 197.9 | 278.5 | 6.43 | |
| 5, S. | 7 | 918 | 131.1 | 294.2 | 6.09 | Used 2 cylinders of engine, with late ignition in one. |
| 6, N. | 9 | 1,170 | 130 | 360 | 4.98 | |
| | | | **"GRAMPUS."**—APRIL 3, 1903. | | | |
| | | | OVER FULL-MILE COURSE. | | | |
| 1, S. | 6 | 912 | 152 | 446.3 | 8.09 | Used 2 cylinders of engine. |
| 2, N. | 8 | 1,202 | 150.25 | 874.5 | 4.13 | |
| 3, S. | 5 | 1,006.5 | 201.30 | 381.6 | 9.45 | Used 3 cylinders of engine. |
| 4, N. | 10 | 2,005 | 200.50 | 627.8 | 5.75 | |
| 5, S. | 6 | 837 | 139.50 | 506 | 7.13 | Used 2 cylinders of engine, with late ignition in one. |
| 6, N. | 12 | 1,620 | 135 | 795.4 | 4.53 | |

**TABLE III.**—STANDARDIZING TRIALS, SUBMERGED, PROPELLED BY MOTOR.

**"PIKE."**

APRIL 4, 1903.—OVER SOUTHERN HALF-MILE COURSE.

| Run. | Elapsed time for counter readings. | Total revolutions. | R. P. M. | Elapsed time over course. | Speed, knots per hour. | Volts. | Ampères. |
|---|---|---|---|---|---|---|---|
| | *Min.* | | | *Sec.* | | | |
| 1, N. | 4 | 700 | 175 | 221.5 | 8.09 | 114.25 | 500 |
| 2, S. | 4 | 693 | 173.25 | 285.7 | 6.27 | 114 | 500 |
| 3, N. | 4 | 647 | 161.75 | 242 | 7.40 | 115 | 400 |
| 4, S. | 4 | 647 | 161.75 | 287.2 | 6.24 | 114.5 | 400 |
| 5, N. | 4 | 607 | 151.75 | 273.1 | 6.56 | 115 | 330 |
| 6, S. | 4 | 608 | 152 | 287.8 | 6.22 | 114.75 | 330 |

**Table III, continued.**—**"GRAMPUS."**—APRIL 3, 1903.

OVER SOUTHERN HALF-MILE COURSE.

| Run. | Elapsed time for counter readings. | Total revolutions. | R. P. M. | Elapsed time over course. | Speed, knots per hour. | Volts. | Ampères. |
|---|---|---|---|---|---|---|---|
| | *Min.* | | | *Sec.* | | | |
| 1, N. | 4 | 696 | 174 | 246.2 | 7.27 | 114.75 | 500 |
| 2, S. | 4 | 696 | 174 | 244.5 | 7.33 | 114.25 | 500 |
| 3, N. | 4 | 658 | 164.25 | 284.9 | 6.29 | 115.25 | 400 |
| 4, S. | 4 | 659 | 164.75 | 245 | 7.31 | 115 | 402 |
| 5, N. | 4 | 616 | 154 | 313.2 | 5.72 | 115.75 | 335 |
| 6, S. | 4 | 617 | 154.25 | 250.8 | 7.14 | 115.50 | 333 |

The curves obtained from these standardized runs are shown on the accompanying plates, Figs. 1 and 2. The corrected maximum speeds obtained during the various runs are as follows:

| Boat. | Light. | Awash. | Submerged. |
|---|---|---|---|
| *Grampus*, knots .. ..... | 8.45 | 7.6 | 7.3 |
| *Pike*, knots..... | 8.51 | 7.44 | 7.18 |

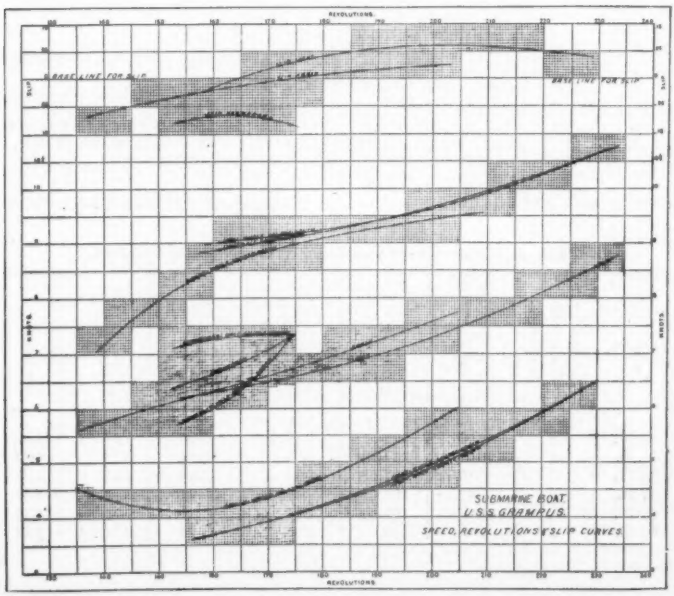



FIG. 2.—U. S. SUBMARINE BOAT "GRAMPUS."—STANDARDIZATION RUNS.

**TABLE IV.**—TEN-KNOT COURSE SURFACE SPEED TRIAL.—LIGHT.

| Time. | Counter number. | | Revolutions per minute. | | ..... | |
|---|---|---|---|---|---|---|
| | *Pike.* April 6, 1903. | *Grampus.* April 10, 1903. | *Pike.* April 6, 1903. | *Grampus.* April 10, 1903. | *Pike.* April 6, 1903. | *Grampus.* April 10, 1903. |
| ..... | 6,800 | 101,000 | ..... | ..... | ..... | ..... |
| '10..... | 9,074 | 103,322 | 227.4 | 232.2 | ..... | ..... |
| '20..... | 11,348 | 105,629 | 227.4 | 230.7 | ..... | ..... |
| '30..... | 13,628 | 107,933 | 228 | 230.4 | ..... | ..... |
| '40..... | 15,900 | 110,236 | 227.2 | 230.3 | ..... | ..... |
| '50..... | 18,178 | 112,542 | 227.8 | 230.6 | ..... | ..... |
| '60..... | 20,458 | 114,849 | 228 | 230.7 | ..... | ..... |
| '70..... | 22,738 | 117,154 | 228 | 230.5 | ..... | ..... |
| '75..... | 23,878 | 118,308 | 228 | 230.8 | ..... | ..... |
| Total ..... | 17,308 | 17,078 | ..... | ..... | ..... | ..... |
| Average..... | ..... | ..... | 230.77 | 227.7 | ..... | ..... |
| Cylinders in use... ..... | ..... | ..... | ..... | ..... | 4 | 4 |
| Mean speed of vessel in knots..... | ..... | ..... | ..... | ..... | 8.55 | 8.47 |
| Distance run, knots..... | ..... | ..... | ..... | ..... | 10.69 | 10.59 |

**TABLE V.**—TEN-KNOT COURSE SURFACE SPEED TRIAL.—AWASH.

| Time. | Counter number. | | Revolutions per minute. | | ..... | |
|---|---|---|---|---|---|---|
| | *Pike.* April 7, 1903. | *Grampus.* April 9, 1903. | *Pike.* April 7, 1903. | *Grampus.* April 9, 1903. | *Pike.* April 7, 1903. | *Grampus.* April 9, 1903. |
| ..... ..... | 52,100 | 28,600 | ..... | ..... | ..... | ..... |
| '10..... | 54,156 | 30,550 | 205.6 | 195 | ..... | ..... |
| '20..... ..... | 56,203 | 32,536 | 204.7 | 198.6 | ..... | ..... |
| '30..... | 58,228 | 34,506 | 202.5 | 197 | ..... | ..... |
| '40..... | 60,275 | 36,473 | 204.7 | 196.7 | ..... | ..... |
| '50..... | 62,297 | 38,476 | 202.2 | 200.3 | ..... | ..... |
| '60..... | 64,329 | 40,462 | 203.2 | 198.6 | ..... | ..... |
| '70..... | 66,358 | 42,442 | 202.9 | 198 | ..... | ..... |
| '80..... | 68,395 | 44,472 | 203.7 | 203 | ..... | ..... |
| '86..... | 69,620 | 45,697 | 204.2 | 204.1 | ..... | ..... |
| Total ..... | 17,520 | 17,097 | ..... | ..... | ..... | ..... |
| Average ..... | ..... | ..... | 203.72 | 198.8 | ..... | 3 |
| Cylinders in use..... | ..... | ..... | ..... | ..... | 3 | |
| Mean speed of vessel in knots..... | ..... | ..... | ..... | ..... | 7.65 | 7.54<br>10.81 |
| Distance run, knots..... | ..... | ..... | ..... | ..... | 10.965 | ..... |

Following this set of trials, the vessels were, on April 6th and on April 9th, put over the longer course of 10 knots. The results of these trials are indicated in Tables Nos. IV and V.

TORPEDO-FIRING TRIAL.

*Grampus*.—On April 7th the *Grampus* was given her torpedo-firing trial, with the following results:

The boat ran, completely submerged, over the full 2-mile course, rising twice en route for observation for periods of 40 seconds and 33 seconds respectively. At the end of the run she again rose to the surface, and 25 seconds later discharged her torpedo at the target, which was 175 yards distant. The torpedo moved in a straight track, passing midway between the buoys constituting the target, thus making a center hit. This torpedo floated at the end of its run and was recovered.

*Pike*.—On April 4th the *Pike* was given her torpedo-firing trial, with the following results:

The boat ran, completely submerged, over the 2-mile course, rising twice en route for observation, for periods of 35 and 25 seconds respectively. At the end of the run she rose to the surface, distant about 200 yards from the target, and fired her torpedo, which failed to make a hit, and sank at the end of its run.

The results are compared below:

| | *Pike*, Apr. 6, '03. | *Grampus*, Apr. 7, '03. |
|---|---|---|
| Total revolutions observed during run | 2,840 | 2,733 |
| Mean rovolutions made per minute | 173.52 | 173.52 |
| speed per hour, knots | 7.14 | 7.27 |
| number of volts | 115.25 | 115 |
| ampères | 500 | 500 |
| depth of immersion, feet, about | 12 | 12 |
| Distance run, knots | 1.95 | 1.91 |

*PIKE* CHOSEN FOR ENDURANCE RUNS.

Owing to the satisfactory results obtained from the *Grampus*, the Board selected by lot the *Pike* to represent the *Grampus* and herself, to make the 3-hour submerged trial, using the electric motor only, and the 12-hour endurance trial under the gasoline engine only. Both of these trials were made successfully.

SUBMERGED ENDURANCE RUN.

The *Pike* was accordingly given this trial on April 9th. As will be seen from the data of the table for this run, she came to the surface 12 times for observations, remaining on the surface for periods ranging from 43 seconds to 5 minutes 21 seconds.

The boat was actually submerged 2 hours 31 minutes 39 seconds, and during this time made an average of 170.44 revolutions per minute, which gives a mean speed of 7.07 knots. During this trial the gases given off by the storage battery and the vapor from the sulphuric acid were plainly noticeable to the eyes, the nose and the lungs; however, the length of time under trial was insufficient to produce any marked inconvenience to the crews (two in number), who worked in alternate shifts of one hour each. The periscope was used on this trial for observations of position.

**TABLE VI.**—THREE HOURS' ENDURANCE TRIAL.—SUBMERGED.

**"PIKE."**

APRIL 9, 1903.—USED ELECTRIC MOTOR.

| Time. | Counter reading. | Time on surface. | Revolutions per min. | Volts. | Ampères. |
|---|---|---|---|---|---|
| A. M. | | *For observation.* | | | |
| 10·39·30 | 70,000 | ... | ... | 115 | 500 |
| 49·30 | 71,702 | ... | 170.2 | 115.25 | 500 |
| 59·30 | 73,412 | 2 m. 14 s. | 171 | 115.5 | 490 |
| 11.09·30 | 75,126 | 5 21 | 171.4 | 115.25 | 495 |
| 19·30 | 76,840 | ... | 171.4 | 115 | 490 |
| 29·30 | 78,554 | 0 59 | 171.4 | 115 | 485 |
| 39·30 | 80,266 | ... | 171.2 | 114.5 | 495 |
| 49·30 | 81,976 | 1 14 | 171 | 114 | 495 |
| 59·30 | 83,687 | ... | 171.1 | 113.75 | 495 |
| P. M. | | | | | |
| 12·09·30 | 85,397 | 3 59 | 171 | 112.75 | 500 |
| 19·30 | 87,109 | 4 26 | 171.2 | 112.75 | 500 |
| 29·30 | 88,811 | 0 43 | 170.2 | 112 | 500 |
| 39·30 | 90,515 | ... | 170.4 | 111.5 | 500 |
| 49·30 | 92,215 | 1 10 | 170 | 111 | 495 |
| 59·30 | 93,912 | 2 30 | 169.7 | 110 | 495 |
| 1·09·30 | 95,601 | 2 45 | 168.9 | 109.75 | 495 |
| 19·30 | 97,294 | 1 00 | 169.3 | 109 | 500 |
| 29·30 | 98,988 | 2 00 | 169.4 | 108 | 510 |
| 39·30 | 100,679 | ... | 169.1 | 106.75 | 525 |

Total time on surface for observation, minutes and seconds..... 28·21
Mean revolutions per minute..... 170.44
Mean speed of vessel, knots..... 7.07
Distance run, knots..... 21.21

### SURFACE ENDURANCE RUNS.

In the 12-hour surface endurance trial of the *Pike* all four cylinders of the gasoline engine were in use. During this trial the boat was secured at the wharf 10 hours 22 minutes 25 seconds, thus leaving 1 hour 37 minutes 35 seconds for the time during which the vessel was under way.

During the 10-knot surface endurance speed trial a mean speed of 8.56 knots was obtained over the course.

### ENDURANCE TRIAL OF GASOLINE ENGINE.

*Pike*.—The endurance trial of the gasoline engine of the *Pike* was commenced with the vessel light and the four cylinders in use. Four stops were made during this trial, for the reasons given below. The details of the performance during this trial are shown below in Table VII.

(1) The vessel being under way, the engine was disconnected and the electric motor put in gear for going alongside the wharf. The motor was then shut down and the gasoline engine was connected.

(2) After returning to the wharf and resuming the trial, a further stop was made to change the position of boat.

(3) Stopped to drop bow of boat.

(4) Stopped to tighten clutch.

**TABLE VII.—"PIKE."**—12-HOURS' ENDURANCE TRIAL.—TIME AT DOCK

Started at 7·43 A. M., under four cylinders, the 10-knot surface endurance speed trial constituting part of the 12-hour endurance trial. At 8·58 A. M. stopped gasoline engine, shifting to motor, to come alongside and secure at dock. At 9·46·25 A. M., being secured at the dock, started ahead with all four cylinders of the gasoline engine to complete the 12-hour endurance trial of the engines.

APRIL 10, 1903.—TIME AT DOCK.—USING GASOLINE ENGINE.

| Time. | Counter reading. | Revolutions per minute. | Remarks. |
|---|---|---|---|
| A. M. | | | |
| 9·46·25 | 123,520 | ..... | Used 4 cylinders. |
| 56·35 | 125,541 | 198.8 | |
| | Stopped 10 minutes and 10 seconds to shift berth. | | |
| 10·36·00 | 127,210 | ..... | Used 4 cylinders. |
| 11·00·00 | 131,940 | 197.1 | |
| 12·00·00 | 143,645 | 195.1 | |
| P. M. | | | |
| 1·00·00 | 155,194 | 192.5 | |
| | Stopped 30 seconds to drop boat's bow. | | |
| 2·00·00 | 166,651 | 192.6 | |
| 3·00·00 | 178,206 | 192.6 | |
| 4·00·00 | 189,588 | 189.7 | |
| 5·00·00 | 200,877 | 188.1 | |
| 6·00·00 | 212,066 | 186.5 | |
| 7·00·00 | 223,354 | 188.1 | |
| 8·00·00 | 234,634 | 188.0 | |
| | Stopped about 2 minutes 15 seconds to tighten clutch. | | |
| 51·00 | 243,928 | 190.6 | |

| | |
|---|---|
| Total revolutions observed at dock | 118,739 |
| Mean revolutions per minute at dock | 190.7 |
| Mean revolutions per minute in free route | 230.74 |
| Revolutions requisite to 8 knots speed, in light condition | 216.2 |
| Time during which gasoline engines were in operation, vessel under way | 1 h. 37 m. 35 s. |
| Same, vessel secured at dock | 10 h. 22 m. 25 s. |
| Total | 12 h. 00 m. 00 s. |

NO DEEP-SEA TRIALS CONDUCTED.

The contractors represented to the Navy Department that it was unsafe to run the 3-hour submerged endurance trial in San Francisco Bay, but the Department declined to omit the run unless the Trial Board should report that it was unsafe to make the tests on the Pacific Coast. The Board having decided that the run could be made there with safety, communicated its decision to the representative of the contractors, who thereupon concluded to make the run in San Francisco Bay, California.

REFUSAL TO SHIFT WEIGHTS WHILE SUBMERGED.

The Board desired to witness the operation of loading a torpedo from the cradle into the tube while the boat was running in a submerged condition. As the builders stated that they were unprepared to perform this evolution without previous

practice, the effect of such action upon the trim of the boat could not be ascertained.

### PERFORMANCE AND CONDITION OF MACHINERY.

The propelling machinery worked successfully during the several trials, and the final inspection showed the gasoline engines to be in good condition. The motor during this trial showed some rise in temperature at various points. The commutator was in fair condition, but the effects of sparking were plainly visible, only about 20 per cent. of the effective brush area remaining. Owing to the breaking of an igniter insulator during the first day's standardization of the *Pike*, one igniter had to be renewed, but this was the only mishap that occurred to the engines of either boat during all the trials.

The performance of the propelling machinery of the *Grampus* was also very satisfactory, and engines were found to be in good condition at the end of the trials.

The facility with which the cylinders of the gasoline engine were alternated was noted when under two or three of the four. While using three cylinders several shifts were made, so that each was given a rest in turn. Under two cylinders all four were used, but in pairs, resting each pair alternately. At no time did the circulating water show any considerable rise in temperature.

### APPLIANCES FOR SUBMERGENCE.

These appliances worked efficiently and satisfactorily throughout the test. The compensating tank can be cleared in a few seconds by opening the communication with the 50-pound air-pressure tank, and thus the boat can be brought from the 300-pound reserve-buoyancy (diving) condition to the "light" condition in a few seconds.

When communication is established through the reducing valve between the air flasks containing air of 2,000 pounds pressure and the 50-pound air-pressure tank, there is a constant leakage through the vent in the valve. The increase in pressure on the auxiliary line and in the living space is very noticeable, and when the boat is running submerged the change in pressure

can be distinctly felt in the ears, particularly so when the pressure is entirely released upon the opening of the hatches after coming to the surface.

### TIME FOR SUBMERGENCE.

With the *Pike* in "light" condition it is said that she can be trimmed ready for diving in about fifteen minutes, this being the time required to stop and disconnect the gasoline engine, to unship the ventilators, to clear and secure the conning-tower hatch, to fill the ballast and the trimming tanks, and to connect the electric motor to the propeller shaft. However, no official test was made to determine the exact time of executing this particular maneuver.

After the boat is put in the "awash" condition, if all openings through the hull are closed and the motor connected to the propeller shaft, the boat can be made ready to dive in two and one-half minutes, the time required to fill the main ballast tank. However, during the standardization runs in the "awash" condition the gasoline engine was in use, and it would have taken considerable time to have dived had the order been given while the craft was in this so-called "awash" condition.

### STEERING AND DIVING.

When running in the light and the awash conditions the diving rudders were set at 8 degrees rise. When in readiness for diving the boat trimmed 2 degrees by the stern, and carried the diving rudders at 10 degrees dive. In diving the angle of rise of the rudders was gradually decreased, and the boat usually went down at an angle of 7 degrees by the head, the maximum noted being 9 degrees.

When running at full speed, or nearly so, in a submerged condition, and when at a depth of about 12 feet, the boat trimmed about 1 degree by the head, and carried the rudders at about 2½ degrees dive. In rising she came up at an angle of about 4½ degrees.

The control of the boat under water and the ease of maintaining an uniform depth is remarkable. Experience, readiness of

resource and constant vigilance are necessary qualifications of the person in control of the diving and the steering gears.

The position of the steering rudders has a marked effect on the action of the diving rudders. Putting the helm hard aport tends to bring the boat up; putting the helm astarboard tends to put the boat down. In turning under water, therefore, it is somewhat difficult to maintain a constant depth. The hand control of both the diving and the steering rudders was excellent.

### MANEUVERING QUALITIES.

On April 11th the *Pike*, in light condition, was given her maneuvering trial, and demonstrated that in this condition, running full speed under the motor, her tactical diameter was about 150 yards, and that she could turn through an angle of 180 degrees in about 1 minute 17 seconds. Running full speed under the gasoline engine her tactical diameter was estimated to be 150 yards, and required 1 minute 14 seconds to turn through an angle of 180 degrees. There was no appreciable difference in either the tactical diameter or in time when turning from starboard to port, or *vice versa*.

With the boat at full speed under the gasoline engine, the screw was reversed in 7 seconds by throwing out the engine clutch and throwing in the motor. The boat was brought to rest in a distance of about 75 yards, 37 seconds after the signal was given.

With the boat at full speed under the motor, the screw was reversed and the boat brought to rest in 34 seconds, in a distance of about 50 yards.

### ACCESSIBILITY OF THE BILGES FOR CLEANING.

The spaces under some of the flats on which rest the engine and the motor are very small. In some of these flats it is difficult, if not impossible, to secure access for cleaning and painting.

These bilges will always be in a very unsatisfactory condition, and the outside plating and the frames enclosing them will always be subjected to the corrosive action of bilge water and decomposing oils. It might be advisable to lift the engine and the motor and fill the inaccessible pockets with cement.

### THE CHARACTER OF THE BOW WAVE.

In reporting upon the character of the wave formed the Naval Constructor, who was a member of the Trial Board, stated:

"At full speed, in the light condition, the water piles up on the bow, just reaching the superstructure. It then falls abruptly, forming a deep hollow, with a crest just abaft the conning tower, and another crest at the tail. For lower speeds and in the awash condition, the wave has the same general form, but the crests are lower and more forward as the speed decreases. At between 6 and 7 knots speed, both in the light and the awash condition, there is a large following eddy at the stern, about ten feet long and two feet wide. This runs forward and breaks. For higher and lower speeds it is also present, but is slightly smaller. This eddy probably accounts for the apparent negative slip obtained from the speed curves. In the submerged condition no wave can be noticed after the conning tower has disappeared. While running in the condition ready for diving very little wave can be noticed, but there is some disturbance of the water due to the conning tower.

### PERSONNEL.

The trial crew which ran the *Grampus* and the *Pike* is the same one that the Holland Company have employed in conducting all their trials, both in this country and in England. Captain Cable handles the boat with consummate skill, begotten of long experience, and his crew is highly efficient. The fact remains, however, that in the thirteen years the Holland Company has been in business he is apparently the only man who has mastered the problem of handling the boat and inspiring the crew with the confidence necessary to achieve even partial success. It should be noted that all the trials made by the Holland boats up to this date have been made practically in smooth water and under conditions entirely favorable to the boat. The Department should conduct a series of tests with a view of determining the seagoing qualities so absolutely necessary to the success of the vessel as an efficient weapon of offense against a blockading fleet.

ADAPTABILITY OF THE SUBMARINE BOAT TO THE REQUIREMENTS OF NAVAL SERVICE.

Before a crew can handle a submarine it is apparent that a vast amount of time must be spent at drill, especially as the success of the diving type of this class of vessel is entirely dependent upon the expertness of individual members of the crew, a fact which should be given due weight when we consider this craft's adaptability for naval purposes.

Knowing that the periscope as at present constructed is valueless for determining distances, and taking into account the uncertainty of vision through the conning-tower lenses in a rough sea, it seems that the complete success of this type of submarine for the purpose intended does not seem to be fully assured.

# NOTES.

## MARINE TURBINES FOR THE GERMAN NAVY.

[From "Zeitschrift des Vereines Deutscher Ingenieure," April 11, 1903.]

The Turbinia Company, the German Parson Marine Company, of Berlin has received two large orders for marine turbine installations from F. Schichau, of Elbing, and the Vulcan Company, of Stettin, to be used for the Imperial Navy of Germany. One installation of 5,000 H.P. is for a sea-going torpedo boat, the other is for 10,000 H.P. for a small cruiser, the *Merkur*. These will be the first ships of the German Navy in which reciprocating engines have been supplanted by steam turbines. For both installations steam will be supplied by water-tube boilers at 15 atmospheric pressures. Two of the five turbines for the torpedo boat are cruising turbines, *i. e.*, intended for low speeds. The turbines are arranged on three shafts, each of which operate two propellers, and make about 700 to 800 revolutions per minute. There are two copper condensers of the usual naval type. The steam is not superheated. The speed of this torpedo boat is to be about 27 knots.

For the cruiser *Merkur* six turbines are contemplated, operating four shafts, each of which carry two propellers. Two of these turbines are for cruising speeds: revolutions, 650 per minute; speed, 22 knots. A notable feature is that the entire plant will be below the protective deck. The screws will be well below the water line, thereby insuring protection from gun fire in battle as well as smooth running during heavy seas.

Compared with merchant vessels, especially ocean greyhounds, the arrangement of cruising turbines represents increased weight of plant due to tactical requirements of naval vessels.

# OBITUARY.

## CHIEF ENGINEER A. W. MORLEY, U. S. N.

Mr. Morley was born in 1834, in Hartford, Conn., of Puritan ancestry, and received a common-school education He learned the trade of machinist in the shops of Woodruff & Beach in that city, and was the leading workman on the engines of the sloop-of-war *Mohican*, which were in that day regarded as large and powerful. He served a time in the drafting room, where he became very proficient, and this led him to become a close student of affairs relating to marine construction.

He went to New York in 1860, and secured employment as engineer on board one of the Fulton Ferry boats. In 1861 he passed a successful examination and entered the Navy as a Third Assistant Engineer. Few men ever entered the corps better equipped practically, and very few have rendered such uniformly successful service.

He served on board the sloop-of-war *Richmond* in the battle below New Orleans, in December, 1862. When promoted to Second Assistant Engineer, he was transferred to the gunboat *Nipsic*, then attached to the South Atlantic blockading squadron. He was afterwards placed in charge of the machine shop which was improvised at Port Royal, and, being a skilled draftsman and practical mechanic, rendered invaluable service to the commander of the station. In case of emergency the practical man, in all ages, has been most depended on; in this case, Mr. Morley was full of resource and was faithful to his trust.

When the civil war ended he served a short period on board the *Pawnee*, and on the iron clads in the Delaware River. He also served on board the famous *Madawaska* during her series of trials in the Gulf Stream. In July, 1866, he was promoted to First Assistant Engineer, and served two years in the Pacific Squadron on board the *Ossipee*, which vessel was one of the first to make an extended cruise along the coast of Alaska and the Aleutian archipelago. This cruise was continued on board the steam sloop *Pensacola*. He served as First Assistant

Engineer at the New York Navy Yard from 1869 to 1872, when he was ordered to the flagship *Powhatan*, and thence to the *Wasp*, on the west coast of South America. He served again at the New York Navy Yard from 1880 to 1882, when he was promoted to the grade of Chief Engineer.

By reason of his superior professional attainments and practical knowledge he was in 1882 placed on duty with the Advisory Board. Under this Board the first steel ships of the Navy were begun, comprising the *Atlanta*, *Boston*, *Chicago* and *Dolphin*.

These vessels were built by Mr. Roach from the designs and under the inspection of this special Board. Mr. Morley became Chief Engineer of the *Dolphin* when she was finished, served in that vessel during her many trials, and finally made a voyage around the world in the ship. He was superintending engineer of the first battleship *Maine*. He was retired in December, 1896, having reached the retiring age.

Mr. Morley was of congenial disposition and great earnestness of character. He generally saw the serious side of things, and, consequently, was oblivious to any joke upon himself. He was a strictly moral, upright man ; one who was adverse to things profane or coarse. While he was careful never to impress his high sense of morality upon others, it was remarkable that every one respected his regard of propriety, and in such a presence refrained from any expression that might offend.

Physically Mr. Morley was possessed of great strength and endurance. He was never so contented as when at work. He knew from experience what a man could do, and he had a method of leading and encouraging subordinates which enabled him to accomplish much. It was his ambition to perform well every duty that devolved upon him. He neither felt it a hardship to assume disagreeable duty nor feared responsibility. He was a respected leader among men, as he was a revered shipmate among his peers. His official career was but a reflection of the love, gentleness and obedience that existed in his home life.

In the quiet of his long sleep this brave officer now rests, but his influence and work will remain as an inspiration to those who had the honor of serving under him.

## ASSOCIATION NOTES.

At a special meeting of the American Society of Naval Engineers, held at the Navy Department, Saturday, April 18, 1903, the votes of the members for the Prize Essay for 1902 were opened and counted.

The gold medal and prize of the Society for the most important contribution to the columns of the JOURNAL during the year was awarded to Lieutenant Commander F. W. Bartlett, U. S. N., for the article "The Repair Ship a Military Auxiliary to the Naval Fleet in Peace and War."

The discussion attendant the award of this prize showed the increasing interest of the members in the work and purpose of the Association.

---

The following circular letter has been issued by the council of the Society, and it is hoped that the members will co-operate with the council in securing an increase of membership of the Association, particularly upon the part of the junior officers of the Service:

"The Council of the American Society of Naval Engineers desires to call the attention of all officers of the Naval Service who are entrusted with the design, installation and operation of naval machinery to the publication that is issued quarterly by the Society.

"This JOURNAL aims to present to those interested in naval development a resumé of engineering progress. Complete and accurate reports of official trials of the new ships of our Navy are prepared by experts, and subjects of special importance relating to marine-engineering affairs are investigated and reported upon by those who have unusual means of securing information.

"The primary purpose of issuing the JOURNAL has been to furnish those who will be called upon in the future to design and

operate the motive power of our warships special information that will assist them in the performance of duty, and thus help to train, for the future needs of the service, a competent and adequate complement of naval engineers.

In view of the fact that existing conditions have prevented many officers from pursuing post-graduate work along engineering lines, it is believed that at the present time the reasons for the issuing of the JOURNAL are as strong as at any period since its publication.

"In urging an increase of membership, particularly upon the part of the junior officers of the line, the council is convinced that this action is in the line of promoting naval efficiency. It is also desired that former commissioned officers of the Service who are engaged directly or indirectly in engineering enterprizes should identify themselves with the Society, thus giving moral and professional support to the purpose of the organization.

"The JOURNAL covers a field that is not occupied by any other technical publication. The engineering conditions in the Navy are such that a publication of the character of the JOURNAL ought to do much to supplement the spirit of the personnel law, whose purpose was to have the future naval officer become a skillful and experienced engineer.

"Active membership is open to all present and former Line and Construction officers of the Navy, and application in writing from such eligibles, when made to the Secretary-Treasurer of the Society, Navy Department, is all that is necessary to insure membership. The annual dues of the Society are $5.00, payable in advance, which includes subscription to the JOURNAL."